FAO
FORESTRY
PAPER

153

ISSN 0258-6150

The world's mangroves 1980–2005

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The world's mangroves 1980–2005

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A thematic study prepared in the framework
of the Global Forest Resources Assessment 2005

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2007

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ISBN 978-92-5-105856-5

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Acknowledgements

The Global Forest Resources Assessment 2005 (FRA 2005) represents a major effort of FAO's Forestry Department, FAO member countries, donors, partners and individual experts. More than 800 people have been directly involved in the process. National correspondents and their teams provided detailed country reports for the assessment. In addition to a detailed report from each country and the main report (FAO, 2006a), several thematic studies were prepared. One of these is *The world's mangroves 1980–2005*.

FAO is grateful for the support of all countries, organizations and experts inside and outside the organization that have made this study possible. Institutional and individual contributors are listed in Annex 1. FAO also recognizes the important collaboration, support and financial resources provided by the International Tropical Timber Organization (ITTO) in the framework of the interagency initiative for a revised *World atlas of mangroves*.

FAO also thanks colleagues in the International Society for Mangrove Ecosystems (ISME), the United Nations Environment Programme World Conservation Monitoring Centre, the Man and Biosphere Programme of the United Nations Educational, Scientific and Cultural Organization and the International Network on Water, Environment and Health of the United Nations University for their collaboration in the data gathering process and remote sensing interpretation; and Spacedat s.r.l. for assistance with the distribution map.

Serena Fortuna was responsible for compiling and analysing the data and preparing this report; Mette Wilkie initiated the study and provided technical guidance; Lynn Ball edited the report; and Flora Dicarlo was responsible for the layout.

Foreword

Mangroves are commonly found along sheltered coastlines in the tropics and subtropics where they fulfil important socio-economic and environmental functions. These include the provision of a large variety of wood and non-wood forest products; coastal protection against the effects of wind, waves and water currents; conservation of biological diversity, including a number of endangered mammals, reptiles, amphibians and birds; protection of coral reefs, sea-grass beds and shipping lanes against siltation; and provision of habitat, spawning grounds and nutrients for a variety of fish and shellfish, including many commercial species.

High population pressure in coastal areas has, however, led to the conversion of many mangrove areas to other uses, including infrastructure, aquaculture, rice and salt production. Numerous case studies describe mangrove losses over time, but information on the status and trends of the extent of mangroves at the global level has, so far, been scarce.

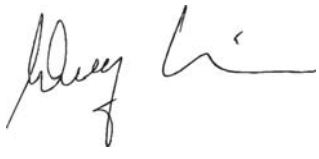
The first attempt at estimating the total mangrove area in the world was undertaken as part of the FAO/United Nations Environment Programme (UNEP) Tropical Forest Resources Assessment in 1980, where the world total was estimated as 15.6 million hectares. More recent estimates have ranged from 12 to 20 million hectares. Countries with small areas of mangroves have been excluded from many studies because of lack of information and because their combined area of mangroves would not significantly affect the world total.

With the preparation of the present report, FAO aims to facilitate access to comprehensive information on the current and past extent of mangroves in all countries and territories in which they exist. The information provided in this report, as well as the gaps in information that it highlights, will assist mangrove managers and policy- and decision-makers worldwide.

The results obtained indicate that global mangrove area is currently about 15.2 million hectares, with the largest areas found in Asia and Africa, followed by North and Central America. An alarming 20 percent of mangrove area, or 3.6 million hectares, has been lost since 1980. More recently, the rate of net loss appears to have slowed down, reflecting an increased awareness of the value of mangrove ecosystems, but the annual rate of loss is still disturbingly high.

As mentioned in this study, changes in methodologies and definitions over time make it difficult to compare results from different assessments. Regular updating of information on the extent and condition of mangroves is needed as an aid to policy- and decision-making for the conservation, management and sustainable use of the world's remaining mangrove ecosystems.

The findings of the present study will also contribute to the revised edition of the *World atlas of mangroves*, first published in 1997 by the International Society for Mangrove Ecosystems (ISME) in collaboration with the International Tropical Timber Organization (ITTO) and the UNEP World Conservation Monitoring Centre (UNEP-WCMC). The second edition is being developed as a joint initiative of ISME, ITTO, the Man and the Biosphere Programme of the United Nations Educational, Scientific and Cultural Organization (UNESCO), UNEP-WCMC, the International Network on Water, Environment and Health of United Nations University, and FAO. The atlas will promote conservation, restoration, management and sustainable use of mangrove ecosystems. Further information on and contacts for this initiative are available at www.fao.org/forestry/site/mangrove-atlas.



Wulf Killmann, Director
Forest Products and Economics Division
FAO Forestry Department

Acronyms and abbreviations

FRA	Global Forest Resources Assessment
GIS	Geographic Information System
ISME	International Society for Mangrove Ecosystems
ITTO	International Tropical Timber Organization
IUCN	World Conservation Union
SIDS	small island developing states
UNEP	United Nations Environment Programme
UNEP-WCMC	UNEP World Conservation Monitoring Centre
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNU	United Nations University

Executive summary

High population pressure in coastal areas has led to the conversion of many mangrove areas to other uses and numerous case studies describe these mangrove losses over time. Nevertheless, information on the current status and trends in the extent of mangroves at the global level is scarce.

With the preparation of the present report, FAO aims to facilitate access to comprehensive information on the current and past extent of mangroves in all countries and areas in which they exist. The information provided in this report, as well as the gaps in information that it highlights, will serve as tools for mangrove managers and for policy- and decision-makers worldwide.

The world's mangroves 1980–2005 was prepared in collaboration with mangrove specialists throughout the world and was cofunded by the International Tropical Timber Organization (ITTO). It builds on a 1980 assessment by FAO and the United Nations Environment Programme (UNEP), on the FAO Global Forest Resources Assessment 2000 (FRA 2000) and 2005 (FRA 2005), and on an extensive literature search and communication with mangrove and forest resources assessment specialists.

Some 2 900 national and subnational data sets on the extent of mangrove ecosystems have been collected during this process, permitting the compilation of an updated list of the most recent reliable estimate for each of the 124 countries and areas in which mangroves are known to exist. Regression analyses based on historical data provided revised estimates for 1980, 1990, 2000 and a forecast for 2005 for each country. Changes in definitions and methodologies over time make it difficult to compare results from different assessments, and the extrapolation to 2005 was constrained by the lack of recent information for a number of countries. This estimate is thus indicative and is likely to change when results from ongoing and future assessments become available.

The results obtained indicate that global mangrove area currently equals about 15.2 million hectares, with the largest areas found in Asia and Africa, followed by North and Central America. An alarming 20 percent, or 3.6 million hectares of mangroves, have been lost since 1980. More recently, the rate of net loss appears to have slowed down, although it is still disturbingly high. About 185 000 ha were lost every year in the 1980s; this figure dropped to some 118 500 ha per year in the 1990s and to 102 000 ha per year (–0.66 percent) during the 2000–2005 period, reflecting an increased awareness of the value of mangrove ecosystems.

Even though mangroves are often used for the collection of wood forest products and as a source of subsistence for local populations, removal of wood and non-wood forest products is rarely the main cause of the loss of mangroves. Human pressure on coastal ecosystems and the competition for land for aquaculture, agriculture, infrastructure and tourism are often high and are major causes of the decrease in area reported. The relatively large negative change rates that occurred in Asia, the Caribbean and Latin America during the 1980s have been caused primarily by large-scale conversion of mangrove areas to aquaculture and tourism infrastructure.

Regular updating of information on the extent and condition of mangroves is needed as an aid to policy- and decision-making for the conservation, management and sustainable use of the world's remaining mangrove ecosystems.

Chapter 1
Introduction

Mangroves are coastal forests found in sheltered estuaries and along river banks and lagoons in the tropics and subtropics. The term 'mangrove' describes both the ecosystem and the plant families that have developed specialized adaptations to live in this tidal environment (Tomlinson, 1986). In a dense mangrove forest, lights and shadows reflect on the water and fish and crabs hide among the submerged roots and trunks. Moving forward may sometimes be possible only by climbing on giant roots or using small boats.

Mangroves have traditionally been widely used and exploited in the past in the majority of countries in which they exist. Knowledge of their current and past extent, condition and uses is essential for forest managers and policy- and decision-makers. The planning of sustainable forest management at the local and national levels depends largely on this information, and the lack of data on the status and distribution of mangroves makes it difficult to prepare successful plans for their conservation. Regular monitoring is thus necessary and may contribute to their conservation, but also to sustainable use of mangroves as a source of wood, food, income and recreational areas for present and future generations.

Although the literature on mangrove forests is extensive and numerous case studies describe their extent and losses over time, global, comprehensive information on the status and trends in the extent of mangroves has been lacking. The first attempt to estimate total mangrove area worldwide was undertaken as part of the FAO and United Nations Environment Programme (UNEP) *Tropical Forest Resources Assessment* in 1980. In that study, the world mangrove total was estimated at 15.6 million hectares, while more recent estimates range from 12 to 20 million hectares (Table 1).

Countries with small areas of mangroves were excluded from many of the earlier studies, probably because of lack of information. The area of mangroves in these countries and areas is, however, relatively small and therefore did not significantly affect the world total.

The world's mangroves 1980–2005 was prepared by FAO in collaboration with mangrove specialists throughout the world, and was cofunded by the International

TABLE 1
Previous estimates of mangrove area worldwide

Reference	Year[a]	No. of countries	Estimated total mangrove area *(ha)*
FAO and UNEP, 1981a,b,c	1980	51	15 642 673
Saenger, Hegerl & Davie, 1983	1983	65	16 221 000
FAO, 1994	1980–1985	56	16 500 000
Groombridge, 1992	1992	87	19 847 861
ITTO & ISME,[b] 1993	1993	54	12 429 115
Fisher & Spalding, 1993	1993	91	19 881 800
Spalding, Blasco & Field, 1997	1997	112	18 100 077
Aizpuru, Achard & Blasco, 2000	2000	112[c]	17 075 600

[a] For FAO and UNEP (1981a,b,c), FAO (1994) and Aizpuru, Achard and Blasco (2000), the data refer to the 'reference year' (i.e. the weighted average year of all the national area estimates), while for the other references, the data refer to the publication year.

[b] Combined figure from three publications: Clough (1993), Diop (1993) and Lacerda (1993).

[c] New estimates were provided for 21 countries; for the remaining countries, the study relied on Spalding, Blasco and Field (1997).

Tropical Timber Organization (ITTO). The main aim of this study was to facilitate access to comprehensive and comparable information on the current and past extent of mangroves in the 124 countries and areas where mangroves are known to exist, highlighting information gaps and providing updated information that may serve as a tool for mangrove managers and policy- and decision-makers worldwide.

The study presents a global overview of mangrove vegetation, species composition and distribution, together with an indication of the main uses and threats in each region. It focuses on present and past mangrove area, and does not provide information on the rate of mangrove degradation or fragmentation. Detailed qualitative and quantitative national-level information for each country is reported in five regional working papers, which complement the information in this report and provide full references (references for the present study are available in Annex 2; the working papers are available at www.fao.org/forestry/site/mangrove/statistics).

MANGROVES

Mangrove ecology and management have been described by many authors over time and the literature on this subject is substantial (for example, Hamilton and Snedaker, 1984; Aksornkoae, 1993; FAO, 1994; UNU, 2004). While it is not the aim of this report to provide a complete review of mangrove forest ecology, a brief overview of mangrove characteristics, distribution and services is provided.

The term 'mangrove' has been discussed by experts and scientists for years (Tomlinson, 1986). It is commonly used to identify trees and shrubs that have developed morphological adaptations to this tidal environment (e.g. aerial roots, salt excretion glands and vivipary of seeds), as well as the ecosystem itself.

Mangroves are salt-tolerant evergreen forests found along sheltered coastlines, shallow-water lagoons, estuaries, rivers or deltas in 124 tropical and subtropical countries and areas, mainly growing on soft substrates. Plants found growing on rocky shores, rooting in silt-filled depressions, may exceptionally be found. The mangrove ecosystem represents an interphase between terrestrial and marine communities, which receive a daily input of water from the ocean (tides) and freshwater, sediments, nutrients and silt deposits from upland rivers. Mangroves may grow as trees or shrubs according to the climate, salinity of the water, topography and edaphic features of the area in which they exist. Human pressure and disturbances also play a critical role in their development; plants living in stressed or polluted environments are often constrained in their development. A zonation in monospecific bands parallel to the shore is frequently visible, generally dictated by local topography, soil composition, tidal ranges and salinity.

Mangrove forests may be found as isolated patches of dwarf stunted trees – in very high salinity and/or disturbed conditions – or as lush forests with a canopy reaching 30–40 metres in height under suitable environmental conditions. In undisturbed and pristine estuaries, mangroves may extend for several kilometres inland. Examples of these extended forests are the Sundarbans, which lies in the delta of three rivers (the Ganges, the Meghna and the Brahmaputra – Bangladesh/India); the Mekong Delta (Viet Nam); the Gambia River delta (the Gambia); the Fly River (Papua New Guinea); and the Florida Everglades (United States of America). The different mangrove ecosystems contain a range of biodiversity (Figure 1).

Only a few plant families (e.g. Rhizophoraceae, Avicenniaceae and Combretaceae) have developed physiological and structural adaptations to the brackish water habitat in which mangroves live. The exact number of species is still under discussion and ranges from 50 to 70 according to different classifications (e.g. Tomlinson, 1986; Saenger, Hegerl and Davie, 1983; Lugo and Snedaker, 1975; Aksornkoae *et al.*, 1992), with the highest species diversity found in Asia, followed by eastern Africa. When moving to the geographical limits of mangroves in subtropical countries and in arid

FIGURE 1
Mangrove ecosystem diversity

S. FORTUNA

Lush mangrove forest (Australia)

M. WILKIE

Avicennia marina *(the Sudan)*

M. WILKIE

Sonneratia *sp. (the Philippines)*

S. FORTUNA

Rocky mangroves (Costa Rica)

zones, mangroves often appear only as small trees, but may still play an essential role for local communities.

At first sight, the most easily recognizable adaptation developed by mangroves to the tidal environment is the aerial rooting system, which is completely or partly exposed to the atmosphere at least part of the day, but covered by water during high tide. Its main functions are the exchange of gases, anchorage of the tree in the muddy soil and absorption of nutrients. However, only the most specialized species (i.e. the major components of the mangrove forest community – 'strict or true mangroves' according to Tomlinson, 1986) have developed this root system, and aerial roots may have different structures according to the species. For example, stilt roots grow from the trunk and lower branches of *Rhizophora* spp. and, to a limited extent, in the sapling stage of *Bruguiera* spp. and *Ceriops* spp. (they become shallow buttresses in

old trees), while 'pneumatophores' – pencil-like extensions of the subterranean rooting system – rise from the ground and extend a long distance from the parental tree in the genera *Avicennia*, *Sonneratia* and *Laguncularia*. In the genera *Bruguiera*, *Ceriops* and *Xylocarpus,* the pneumatophores may form a series of arched or knee shapes during their horizontal growth (the so-called 'knee roots'). According to Tomlinson (1986), minor components of the mangrove community may or may not have this aerial rooting system, while associated species develop it only in a very few species (e.g. in the genera *Oncosperma, Phoenix* and *Raphia*).

Processing excessive salt in the water absorbed is one of the biggest challenges in the salty environment in which mangroves live. These plants have developed several methods, according to the species, to desalinate ocean water. They may exclude the uptake of salt at the root level, or remove excess salt at the leaf level, by using salt excretion glands (species in the genera *Avicennia*, *Aegiceras* and *Aegialitis*), by cuticular transpiration at the leaf level, or by accumulating the salt in leaf tissues and then shedding the leaves.

To increase successful plant propagation, the most specialized mangrove families have developed some very efficient reproduction systems. In the Rhizophoraceae family, the fruit, and therefore the seed, is not released. It germinates on the parental tree, and the seedling itself is used as the propagule (vivipary) (Juncosa, 1982). In this viviparous species, the embryo has no dormancy and is detached only when mature and ready to be established. Other species, for example in the genera *Aegiceras*, *Avicennia*, *Nypa* and *Pelliciera*, have developed cryptovivipary (Carey, 1934), in which the embryo emerges from the seed, but not from the fruit until after it abscises.

FUNCTIONS AND USES OF MANGROVES

Mangrove forest ecosystems fulfil a number of important functions and provide a wide range of services at the local and national levels (Box). Fishermen, farmers and other rural populations depend on them as a source of wood (e.g. timber, poles, posts, fuelwood, charcoal) and non-wood forest products (food, thatch – especially from nipa palm – fodder, alcohol, sugar, medicine and honey). Mangroves were also often used for the production of tannin suitable for leather work and for the curing and dyeing of fishing nets. However, this production has declined in recent years, mainly because of the introduction of nylon fishing nets and the use of chrome as the predominant agent for curing leather (FAO, 1994).

Mangroves support the conservation of biological diversity by providing habitats, spawning grounds, nurseries and nutrients for a number of animals. These include several endangered species and range from reptiles (e.g. crocodiles, iguanas and snakes) and amphibians to mammals (tigers – including the famous *Panthera tigris tigris,* the Royal Bengal tiger – deer, otters, manatees and dolphins) and birds (herons, egrets, pelicans and eagles, to cite just a few). A wide range of commercial and non-commercial fish and shellfish also depends on these coastal forests. The role of mangroves in the marine food chain is crucial. According to Kapetsky (1985), the average yield of fish and shellfish in mangrove areas is about 90 kg per hectare, with maximum yield of up to 225 kg per hectare (FAO, 1994). When mangrove forests are destroyed, declines in local fish catches often result. Assessments of the links between mangrove forests and the fishery sector suggested that for every hectare of forest cleared, nearby coastal fisheries lose some 480 kg of fish per year (MacKinnon and MacKinnon, 1986).

Mangrove ecosystems are also used for aquaculture, both as open-water estuarine mariculture (e.g. oysters and mussels) and as pond culture (mainly for shrimps). Because of its high economic return, shrimp farming has been promoted to boost the national economy and alleviate poverty in several countries. This activity is often an answer to the financial constraints on many farmers and local communities and

BOX

Mangrove uses – wood and non-wood forest products

Fuel
Fuelwood
Charcoal

Construction
Timber, scaffolding
Heavy construction
Railway sleepers
Mining props
Boat-building
Dock pilings
Beams and poles
Flooring, panelling
Thatch or matting
Fence posts, chipboard

Fishing
Fishing stakes
Fishing boats
Wood for smoking fish
Tannin for nets/lines
Fish-attracting shelters

Textile, leather
Synthetic fibres (rayon)
Dye for cloth
Tannin for leather preservation

Other natural products
Fish
Crustaceans
Honey
Wax
Birds
Mammals
Reptiles
Other fauna

Food, drugs and beverages
Sugar
Alcohol
Cooking oil
Vinegar
Tea substitute
Fermented drinks
Dessert topping
Condiments (bark)
Sweetmeats (propagules)
Vegetables (fruit/leaves)

Agriculture
Fodder

Household items
Glue
Hairdressing oil
Tool handles
Rice mortar
Toys
Match sticks
Incense

Other forest products
Packing boxes
Wood for smoking sheet rubber
Medicines

Paper products
Paper – various

Source: modified from FAO, 1994.

represents a source of employment. However, if unsustainably planned and managed, it can lead to uncontrolled deforestation and to pollution of coastal waters, damaged or totally destroyed coastal ecosystems and the loss of the services and benefits provided by mangroves. A series of international principles for responsible shrimp farming have been prepared (FAO/Network of Aquaculture Centres in Asia-Pacific/UNEP/World Bank/Worldwide Fund for Nature, 2006; FAO, 1995a), with the main aim of offering guidance on reducing the sector's environmental impact while boosting its contribution to poverty alleviation. The principles were welcomed by many countries (FAO, 2006b)) and will hopefully provide support to the development of more eco-friendly shrimp production.

The increasing popularity of ecotourism activities also represents a potentially valuable and sustainable source of income for many local populations, especially where the forests are easy accessible.

Mangroves also help protect coral reefs, sea-grass beds and shipping lanes by entrapping upland runoff sediments. This is a key function in preventing and reducing coastal erosion and provides nearby communities with protection against the effects of wind, waves and water currents. In the aftermath of the 2004 Indian Ocean tsunami, the protective role of mangroves and other coastal forests and trees received considerable attention, both in the press and in academic circles. After more than two years, there are still contrasting views on this issue: eyewitnesses reported that coastal forests had saved villages from the destruction and lives, while some analyses asserted that elevation and distance from the coast were more significant determinants of protection than the forest cover itself.

Even though additional studies are needed to define specific details and limits of this protective function, the numerous studies and workshops undertaken on this topic over the past couple of years have brought to light a number of interesting factors. Experts and scientists agree that thick and dense coastal forest belts, if well designed and managed, have the potential to act as bioshields for the protection of people and other assets against some tsunamis and other coastal hazards (i.e. coastal erosion, cyclones, wind and salt spray). However, generalizations – and the creation of a false sense of protection provided by these bioshields – should be avoided, because mangroves and other coastal forests are not able to provide effective protection against all levels of hazards and may not be effective as shields against tsunamis as severe as the one that occurred in 2004. A full description of the factors to be taken into account with regard to enhancing the protective functions of mangroves and other coastal forests goes beyond the scope of this report. Interested readers are referred to FAO (2007) for further information.

UNDERVALUED RESOURCES

Despite the many services and benefits provided by mangroves, these coastal forests have often been undervalued and viewed as wastelands and unhealthy environments. The high population pressures frequently present in coastal zones have in some places led to the conversion of mangrove areas for urban development. In order to increase food security, boost national economies and improve living standards, many governments encouraged the development of shrimp and fish farming, agriculture, and salt and rice production in mangrove areas. Mangroves have also been fragmented and degraded through overexploitation for wood forest products and pollution. Indirectly, habitats have been lost because of dam construction on rivers, which often diverts water and modifies the input of sediments, nutrients and freshwater. Even though dense mangrove forests can be important in coastal protection, natural disasters should also be listed among the possible causes of degradation: several tropical countries are frequently hit by cyclones, typhoons and strong winds, and the trees in the front lines may be damaged and/or uprooted during these catastrophes.

Over the last few years, however, awareness of the importance and value of mangrove ecosystems has been growing, leading to the preparation and implementation of new legislation and to better protection and management of mangrove resources. In some countries, restoration or re-expansion of mangrove areas through natural regeneration or active planting has also been observed. In addition, many governments are increasingly recognizing the importance of mangroves to fisheries, forestry, coastal protection and wildlife. Despite these positive signs, much still needs to be done to effectively conserve these vital ecosystems.

Chapter 2
Methodology

This study builds on the Tropical Forest Resources Assessment 1980 (FAO and UNEP, 1981a,b,c) and on information provided to the Global Forest Resources Assessment 2000 (FRA 2000) (FAO, 2001) and FRA 2005 (FAO, 2006a). While the first of these assessments specifically included mangroves as a distinct forest class, countries were asked to document several variables for FRA 2000 and FRA 2005, including the current forest area according to forest types, using their own classification systems. Since mangroves form a distinct and relatively easily defined forest type, most countries with mangroves provided specific information on their extent. An extensive literature search and inputs from national mangrove experts (Annex 1) yielded additional information. Where recent national information was lacking, an estimate of mangrove area was obtained through interpretation of remote sensing data (a joint effort between UNEP-WCMC and FAO). Local authorities and national experts played a key role in the process of gathering and reviewing the extensive quantitative and qualitative country-level information collected.

INFORMATION GATHERING AND DATA VALIDATION

Based on information collected during a preliminary assessment (FAO, 2003), a national profile was compiled for each country that has mangroves. Besides the quantitative data on mangrove area trends over time, the national profiles included qualitative information on mangrove species composition and distribution, an indication of their uses, and threats to their survival. This documentation, together with a country-specific questionnaire, was distributed to 110 mangrove experts worldwide and to 107 officially nominated national correspondents to FRA 2005 for feedback. To involve an even broader range of national experts, the information was also circulated to members of the International Society for Mangrove Ecosystems (ISME) – an international non-profit and non-governmental scientific society of mangrove experts – to specific discussion lists, and uploaded on an interactive Web page.

The data collection process first entailed a search for references containing recent reliable national information on the extent of mangroves from countries worldwide. Past estimates were also sought in order to facilitate an analysis of area changes over time in each country. Subnational data for provinces and forests were included where available; in a few cases in which past estimates were lacking at the national level, the subnational figures were used to create a composite national estimate to be used in trend analysis.

Cross-checking of data was done where possible and the information analysed with the assistance of specialists. An initial screening of results included the weeding out of duplicates, discarding of rough 'guesstimates' and selection of one estimate for the trend analyses for those years for which more than one was available. This was followed by regression analyses (best fit of linear, polynomial, logarithmic and power curves) of the most reliable data over time for each country, which provided estimates for 1980, 1990, 2000 and 2005. Where insufficient information was available (i.e. only one estimate within the last 30 years), with no possibility of updating through Landsat imagery interpretation or through the annual forest change rate for all forest types in the country as reported in FAO (2006a), the area was assumed to have remained constant unless qualitative information indicated otherwise. Similarly, where the information

collected was not sufficient for a correct regression analysis, the extrapolation to year 2005 was based on the annual forest change rate for the period 2000–2005 (FAO, 2006a) applied to the latest reliable estimate.

The input of the specialists played a crucial role, facilitating the compilation of updated and nationally validated country profiles and the determination of the most recent reliable area estimate for each country/area. Moreover, drafts of the study were sent to all the official national correspondents for the FRA process for comments and validation.

Details of reference sources, area estimates and regressions used for individual countries are provided in the five regional working papers cited in Annex 2, which provide information complementary to this report.

DEFINITION OF TRUE MANGROVE SPECIES

Following the classification in Tomlinson (1986), mangroves may be divided into three groups according to their features and morphological adaptations: major elements (strict or true mangroves, which are found exclusively in the mangrove habitat), minor elements and mangrove associates. In the present study, Tomlinson's list of major and minor mangrove species has been adopted and supplemented with selected species listed in Saenger, Hegerl and Davie (1983), which have been considered to be commonly found in mangrove ecosystems. Detailed species lists by country are provided in the regional chapters. Associated species (e.g. in the genera *Caesalpinia*, *Mora*, *Thespesia*) are often found at the landward edge of mangrove ecosystems (also called the 'back mangrove'), along river banks or in beach forests, yet without featuring all the highly specific adaptations developed in the true mangrove species. Consequently, they have not been included in the 'true mangrove species' list in Annex 3.

Chapter 3
Global overview

A total of 124 countries and areas were identified as containing one or more true mangrove species (Tomlinson, 1986; Saenger, Hegerl and Davie, 1983) (see Annex 3). Table 2 presents an overview of the status and trends in extent of mangrove area at the regional level. The reference year given in the table for the most recent reliable estimate is the area-weighted average year. A list of the most recent reliable national/area estimates for each country or territory is presented in Table 3.

The considerable collection of quantitative and qualitative information yielded some 2 900 national and subnational data sets, of which just over 1 100 were national estimates. After elimination of duplicates, about 900 estimates remained. The period of time covered by the present assessment is very broad, with the earliest estimates dating back to 1888 for Australia, 1918 for the Philippines and 1921 for Madagascar. For some countries (e.g. Australia, Japan, Malaysia and Wallis and Futuna Islands), the most recent estimates date from 2005. Quantitative data on current and past extent of mangroves were not available for the British Indian Ocean Territory, Christmas Island, French Polynesia, Maldives, Marshall Islands, Sao Tome and Principe and Tokelau. However the extent of mangroves estimated to be present in these seven countries and areas is low and, even though very relevant locally, would not significantly influence the world total.

According to trend analyses of the available data, some 15.2 million hectares of mangroves are estimated to exist worldwide as of 2005, down from 18.8 million hectares in 1980. The most extensive mangrove area is found in Asia, followed by Africa and North and Central America (Table 3 and Figure 2). Five countries (Indonesia, Australia, Brazil, Nigeria and Mexico) together account for 48 percent of the total global area, and 65 percent of the total mangrove area is found in just ten countries (Figure 3). The remaining 35 percent is spread over 114 countries and areas, of which 60 have less than 10 000 ha of mangroves each.

Asia, which according to FAO (2006a) is the region with the lowest forest cover in terms of percentage of land area, has the largest extent of mangroves (approximately 6 million hectares), and five of the ten countries with the largest extent of mangroves worldwide are found in this region.

Human pressure on coastal ecosystems is often high, with land competition for aquaculture, agriculture, infrastructure and tourism. The consequent conversion of mangrove areas to other uses over the past decades has been alarming. However,

TABLE 2
Current and past extent of mangroves by region (1980–2005)

Region	Most recent reliable estimate		1980	1990	Annual change 1980–1990		2000	Annual change 1990–2000		2005	Annual change 2000–2005	
	1 000 ha	Ref. year	1 000 ha	1 000 ha	1 000 ha	%	1 000 ha	1 000 ha	%	1 000 ha	1 000 ha	%
Africa	3 243	1997	3 670	3 428	–24	–0.68	3 218	–21	–0.63	3 160	–12	–0.36
Asia	6 048	2002	7 769	6 741	–103	–1.41	6 163	–58	–0.89	5 858	–61	–1.01
North and Central America	2 358	2000	2 951	2 592	–36	–1.29	2 352	–24	–0.97	2 263	–18	–0.77
Oceania	2 019	2003	2 181	2 090	–9	–0.42	2 012	–8	–0.38	1 972	–8	–0.39
South America	2 038	1992	2 222	2 073	–15	–0.69	1 996	–8	–0.38	1 978	–4	–0.18
World	**15 705**	**2000**	**18 794**	**16 925**	**–187**	**–1.04**	**15 740**	**–118**	**–0.72**	**15 231**	**–102**	**–0.66**

TABLE 3
Most recent reliable mangrove area estimate by country/area

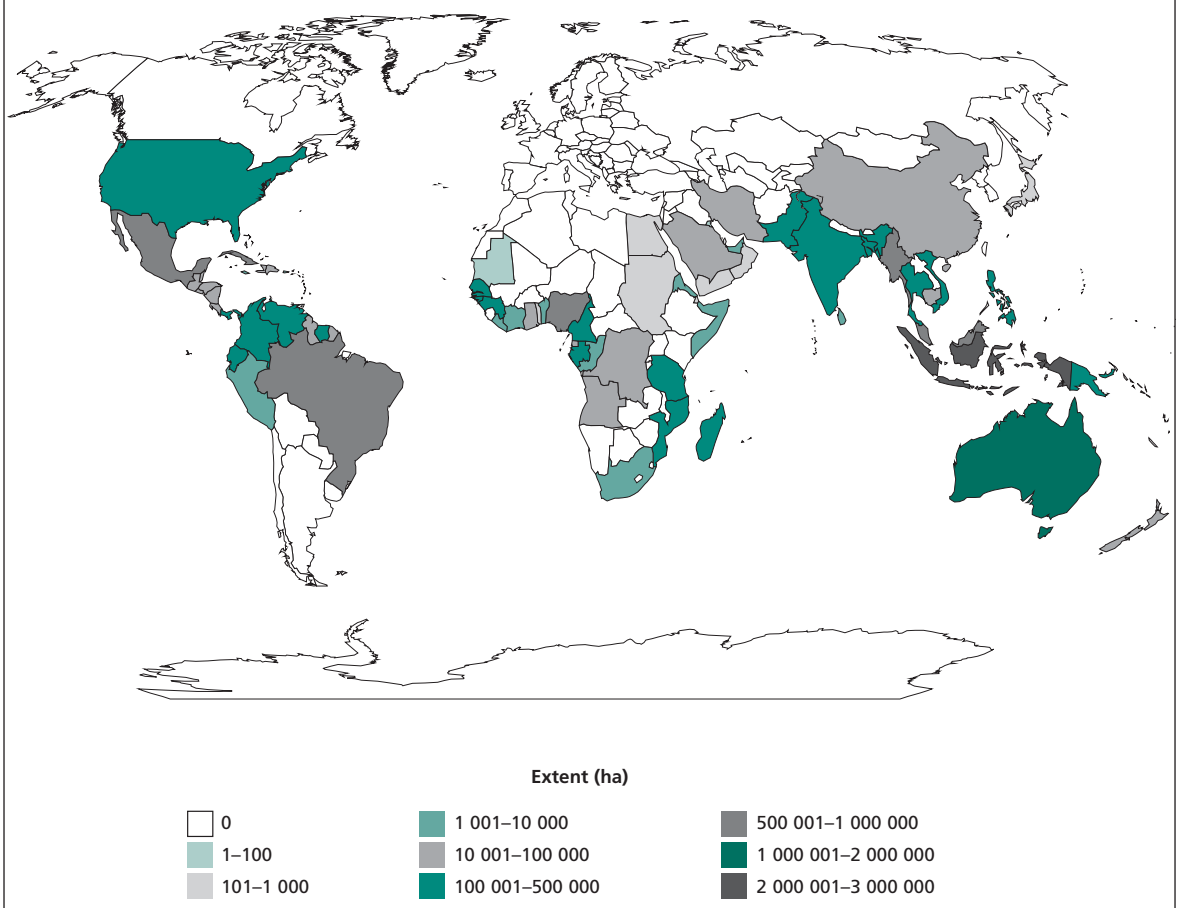
Country/area	ha	Year
Angola	33 600	2000
Benin	1 700	1989
British Indian Ocean Territory	n.a.	n.a.
Cameroon	251 545	2000
Comoros	117	2002
Congo	8 000	2003
Côte d'Ivoire	9 940	2000
Dem. Rep. of the Congo	19 600	2000
Djibouti	1 000	1985
Egypt	512	2002
Equatorial Guinea	25 700	1995
Eritrea	6 400	1997
Gabon	152 940	2000
Gambia	58 100	2000
Ghana	13 729	2000
Guinea	276 342	1997
Guinea-Bissau	248 400	1990
Kenya	52 980	1982
Liberia	9 244	2000
Madagascar	303 814	2004
Mauritania	104	1993
Mauritius	120	2004
Mayotte	668	1989
Mozambique	392 749	1997
Nigeria	997 700	1995
Sao Tome and Principe	n.a.	n.a.
Senegal	127 702	2000
Seychelles	2 900	1960
Sierra Leone	105 300	2000
Somalia	10 000	1975
South Africa	3 054	1999
Sudan	500	1995
Togo	1 094	2000
United Rep. of Tanzania	127 200	2000
Total Africa	**3 242 754**	**1997**
Bahrain	100	1992
Bangladesh	476 215	1995
Brunei Darussalam	18 418	1996
Cambodia	72 835	1997
China	22 480	2001
India	446 100	2003
Indonesia	3 062 300	2003
Iran, Islamic Rep. of	19 234	1997
Japan	800	2005
Kuwait	5	2004
Malaysia	564 971	2005
Maldives	n.a.	n.a.
Myanmar	518 646	1999
Oman	1 088	1995
Pakistan	158 000	2001
Philippines	247 362	2003
Qatar	500	1992
Saudi Arabia	20 400	1985
Singapore	500	1990
Sri Lanka	9 530	1996
Thailand	244 085	2000
Timor-Leste	1 802	2000
United Arab Emirates	4 000	1999
Viet Nam	157 500	2000
Yemen	927	1993
Total Asia	**6 047 798**	**2002**
American Samoa	52	2003
Australia	1 451 411	2005
Christmas Island	n.a.	n.a.
Fiji	42 464	1991
French Polynesia	n.a.	n.a.
Guam	70	1993
Kiribati	258	1995
Marshall Islands	n.a.	n.a.
Micronesia (Fed. States of)	8 564	1983
Nauru	2	1991
New Caledonia	17 140	2003
New Zealand	26 032	2001
Niue	3 000	1981
Northern Mariana Islands	7	1976
Palau	4 708	1985
Papua New Guinea	410 000	2000
Samoa	370	1999
Solomon Islands	50 572	1993
Tokelau	n.a.	n.a.
Tonga	1 305	1997
Tuvalu	40	1993
Vanuatu	2 519	1993
Wallis and Futuna Islands	25	2005
Total Oceania	**2 018 537**	**2003**
Anguilla	90	1991
Antigua and Barbuda	1 175	1991
Aruba	420	1986
Bahamas	141 957	1991
Barbados	4	2004
Belize	78 511	1990
Bermuda	16	1992
British Virgin Islands	587	2001
Cayman Islands	7 830	1998
Costa Rica	41 840	2000
Cuba	545 805	2003
Dominica	10	1991

TABLE 3 (continued)
Most recent reliable mangrove area estimate by country/area

Country/area	ha	Year
Dominican Republic	21 215	1998
El Salvador	28 000	2004
Grenada	255	1992
Guadeloupe	2 950	1997
Guatemala	17 727	1999
Haiti	15 000	1988
Honduras	78 668	2000
Jamaica	9 731	1997
Martinique	1 840	1998
Mexico	882 032	2002
Montserrat	5	1991
Netherlands Antilles	1 138	1980
Nicaragua	69 050	1998
Panama	174 435	2000
Puerto Rico	8 870	2000
Saint Kitts and Nevis	79	1991
Saint Lucia	200	2002
Saint Vincent and the Grenadines	51	1991
Trinidad and Tobago	7 150	1991
Turks and Caicos Islands	23 600	1988
United States	197 648	2001
United States Virgin Islands	216	1999
Total North and Central America	**2 358 105**	**2000**
Brazil	1 012 376	1991
Colombia	371 250	1997
Ecuador	149 556	1999
French Guiana	55 000	1980
Guyana	80 432	1992
Peru	4 550	1995
Suriname	114 600	1998
Venezuela (Bolivarian Rep. of)	250 000	1986
Total South America	**2 037 764**	**1992**

Note: n.a. = not available.

FIGURE 2
Extent of mangrove area worldwide, 2005



although mangroves still face major threats, the rate of loss has recently been decreasing – from some 187 000 ha lost annually in the 1980s (–1.04 percent per year) to 102 000 ha annually (–0.66 percent per year) during the 2000–2005 period. The figures suggest that during the past 25 years about 3.6 million hectares have been lost, corresponding to some 20 percent of the global mangrove area in 1980. At the regional level, Asia suffered the largest net loss: more than 1.9 million hectares since 1980, mainly due to changes in land use from 1980 to 1990. North and Central America and Africa also contributed significantly to the decrease in mangrove area at the global level, with losses of about 690 000 and 510 000 ha respectively over the last 25 years. On a positive note, analysis of the trend in mangrove area changes in the last five years (2000–2005), shows a reduction of the rate of loss in all regions (Figure 4).

FIGURE 3
Percentage of world mangrove area by country, 2005

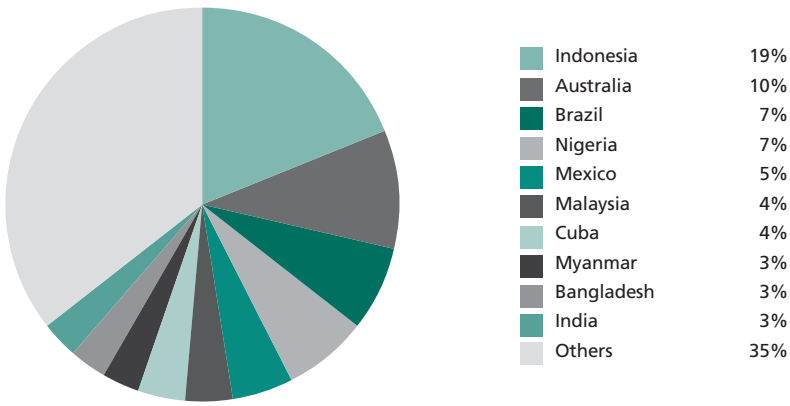
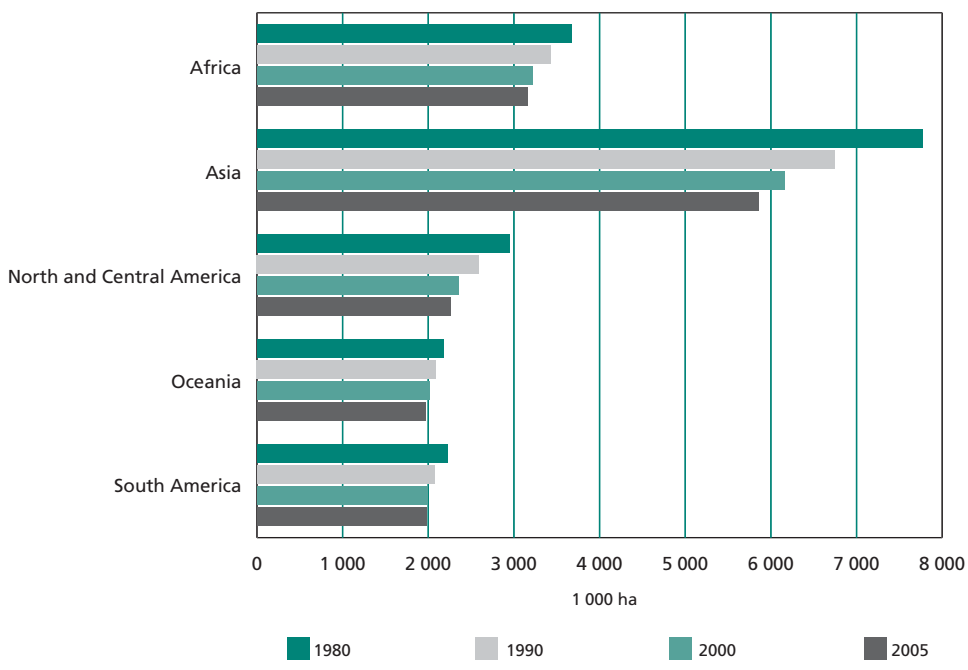


FIGURE 4
Changes in world mangrove area, 1980–2005



Mangroves often offer a source of wood products, providing subsistence for local populations. Wood removal, however, is rarely the main cause of mangrove loss. The major cause of clearings and losses over time is competition for land – for urban development, tourism, agriculture or shrimp-pond construction. More specifically, the relatively large mangrove negative change rates of the 1980s in Asia, the Caribbean and Latin America have been caused primarily by large-scale conversion of these areas for aquaculture and tourism infrastructure. Most countries have now banned the clearing of mangrove areas for aquaculture and require environmental impact assessments prior to large-scale conversion of these areas to other uses.

At the country level, Indonesia, Mexico, Pakistan, Papua New Guinea and Panama recorded the largest losses of mangroves during the 1980s. A total of some 1 million hectares were lost in these five countries – a land area comparable to Jamaica. In the 1990s Pakistan and Panama succeeded in reducing their rate of mangrove loss. Conversely, Viet Nam, Malaysia and Madagascar suffered increased clearing and moved into the top five countries with major area losses in the 1990s and/or 2000–2005. Even though efforts are under way to decrease mangrove loss, some 500 000 ha have still been lost worldwide within the period 2000–2005.

In relative terms, countries with high negative change rates include Singapore, Barbados, Pakistan and the Republic of the Congo in the 1980s; Barbados, Oman, Samoa and Timor-Leste in the 1990s and Barbados, Liberia, Antigua and Barbuda and Benin from 2000 to 2005.

On a positive note, a number of countries have registered an increase in mangrove area over time, including Bangladesh. Here, the Sundarbans Reserved Forest (the Bangladeshi section of the Sundarbans) – part of the largest mangrove area in the world – is well protected, and no major changes have occurred during the last few decades. In addition, successful efforts in coastal afforestation have contributed to an increase in the extent of mangrove area despite some losses outside the reserve. A long tradition of plantation programmes is found in other countries as well and has led to an increase in the extent of mangrove area. The recolonization and natural regeneration properties of these forests also help to increase their extent. In Ecuador, for example, the abandoning of ponds and structures for shrimp and salt production resulted in a recolonization of various sites. It should, however, be noted that in a few cases, a slight positive or negative trend may have been caused by changes in methodology or definitions or, as in the United Arab Emirates, by the discovery of new mangrove areas not included in previous assessments.

More than 20 countries are reported as having had no significant change in mangrove area over time. In some of these countries and areas, this may be caused by the limited quantitative information available at the time the study was prepared. In a few of them – Saudi Arabia and the Sudan for example – although the extent did not appear to have changed significantly over the last decades, the quality of the stands may have severely deteriorated, due primarily to camel grazing, pollution and/or oil spills.

Chapter 4
Africa

VEGETATION AND SPECIES COMPOSITION

Mangroves are found in almost all countries along the west and east coasts of Africa, spreading from Mauritania to Angola on the west coast, and from Egypt to South Africa on the east coast, including Madagascar and several other islands. They are absent from Namibia, probably due to the semi-arid, desert-like climate, with low and irregular rainfall, a lack of warming currents and of favourable topographical features.

Forest structure and species composition differ significantly from one coast to the other, as is described in the following paragraphs.

On the east coast they generally form narrow fringe communities along the shores or small patches in estuaries, along seasonal creeks or in lagoons. The trees do not usually grow to more than 10 m in height, with a minimum height of 0.7–2 m in the Sudan and 1–2 m in South Africa. Madagascar (especially the northwest region), Mozambique and the United Republic of Tanzania represent the few exceptions: the extensive deltas and estuaries found in these countries allow the development of well-extended communities, with tree heights reaching 25–30 m. The Messalo and Zambezi river deltas (Mozambique) are home to some of the most extensive mangrove forests in the region.

On the west coast well-developed mangroves are often found in large river deltas, in lagoons, along sheltered coastlines and on tidal flats. These forests may extend several kilometres inland, as happens in the Gambia and Guinea-Bissau, where major forests are found even 100–160 km upstream (e.g. Tendaba, Elephant Island and Dan Kun Ku Island). Along the coast in Cameroon and Nigeria, mangrove trees may reach heights of up to 40 m. Among the best-structured forests in western Africa are the Niger Delta communities (Nigeria), with stands stretching 30–40 km inland; the mouth of the Gambia River; the Komo estuary (Gabon), with *Rhizophora* spp. attaining heights of 30 m; and the Yawri Bay (Sierra Leone), a shallow coastal wetland that includes some 14 percent of the total national mangrove area.

As reported in Tables 4 and 5, the east coast, with its 14 true mangrove species, features a higher species diversity than the west coast, where only seven species occur naturally, usually homogeneously distributed throughout all the countries. The highest diversity is found in Mozambique, Kenya and Seychelles. A few species, such as *Avicennia marina* and *Rhizophora mucronata,* have a wide distribution along this coast and are found in most of the eastern countries. On the other hand, other species grow only in one or a few countries, for example *Bruguiera cylindrica* (found in Mozambique) and *Ceriops somalensis* (endemic to Somalia).

Mangrove communities in Egypt and Mauritania represent the northernmost stands for eastern and western Africa, respectively, and owing to their extreme environmental conditions (high salinity, low rainfall and extreme temperatures), the trees are generally stunted, rarely exceeding 5 m in height. In these countries mangrove species diversity and cover are fairly low. However, as mangroves are often the only forest ecosystem found along the coasts, they provide needed resources for local communities and a habitat for a wide range of wildlife, and are important in the conservation of forest genetic resources.

TABLE 4
Mangrove species composition in Western Africa

Species	Angola	Benin	Cameroon	Congo	Dem. Rep. of the Congo	Côte d'Ivoire	Equatorial Guinea	Gabon	Gambia	Ghana	Guinea	Guinea-Bissau	Liberia	Mauritania	Nigeria	Sao Tome and Principe	Senegal	Sierra Leone	Togo
Acrostichum aureum	√	√	√	√	√	√		√	√	√	√		√		√	√	√	?	
Avicennia germinans	√	√	√	√[a]	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Conocarpus erectus	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	
Laguncularia racemosa	√	√	√	√	√	√		√	√	√	√	√			√		√	√	
Nypa fruticans[b]			√												√				
Rhizophora harrisonii	√	√	√	√				√	√	√	√	√	√		√	√	√	√	
Rhizophora mangle	√		√		√			√	√		√	√	√		√		√	√	
Rhizophora racemosa	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√
Total no. of species	**7**	**6**	**8**	**6**	**6**	**5**	**2**	**7**	**7**	**6**	**7**	**6**	**6**	**3**	**8**	**4**	**7**	**6**	**2**

[a] Kaya (2003 and unpublished, 2004) differentiates specimens of *A. germinans* from those of *A. nitida*. However, these two species are treated as the same in Tomlinson (1986) and in the present report.
[b] Introduced in both countries.

TABLE 5
Mangrove species composition in Eastern Africa

Species	British Indian Ocean Territory	Comoros	Djibouti	Egypt	Eritrea	Kenya	Madagascar	Mauritius	Mayotte	Mozambique	Seychelles	Somalia	South Africa	Sudan	United Rep. of Tanzania
Acrostichum aureum							√			√	√		√		√
Avicennia germinans									√						
Avicennia marina		√	√	√	√	√	√			√	√	√	√	√	√
Bruguiera gymnorrhiza		√			√	√	?[a]	√	√	√	√	√	√	√[b]	
Bruguiera cylindrica										√					
Ceriops somalensis												√			
Ceriops tagal					√	√	√		√	√	√	√	√		√
Conocarpus erectus															
Heritiera littoralis						√	√		√	√					
Laguncularia racemosa															
Lumnitzera racemosa	√	√				√	√			√	√	√	√		√
Pemphis acidula											√				
Rhizophora harrisonii															
Rhizophora mangle															
Rhizophora mucronata		√	√	√	√	√	√	√	√	√	√	√	√	√[b]	√
Rhizophora racemosa															
Sonneratia alba		√				√	√		√	√	√	√			
Xylocarpus granatum						√	√			√	√	√	√		
Xylocarpus mekongensis						√									
Total no. of species	**1**	**5**	**2**	**2**	**4**	**9**	**9**	**2**	**6**	**10**	**9**	**8**	**7**	**3**	**5**

[a] Uncertain.
[b] May have become extinct.

MANGROVE RESOURCES: STATUS AND TRENDS 1980–2005

Analysis of the data shows that total mangrove forest cover for 2005 in Africa is estimated at 3.2 million hectares (Table 6).

As can be seen in Table 6 and Figure 5, some 70 percent of all African mangroves can be found in just five countries: Nigeria, Mozambique, Madagascar, Guinea and Cameroon. These extensive mangrove forests have an important role in national

TABLE 6
Status and trends in mangrove area – Africa (1980–2005)

Country/area	Most recent reliable estimate		1980	1990	Annual change 1980–1990		2000	Annual change 1990–2000		2005	Annual change 2000–2005	
	ha	Ref. year	ha	ha	ha	%	ha	ha	%	ha	ha	%
Angola	33 600	2000	53 000	43 300	–970	–2.0	33 600	–970	–2.5	33 000	–120	–0.4
Benin	1 700	1989	2 100	1 650	–45	–2.4	1 350	–30	–2.0	1 150	–40	–3.2
British Indian Ocean Territory	n.a.	n.a.										
Cameroon	251 545	2000	272 000	256 300	–1 570	–0.6	251 500	–480	–0.2	250 000	–300	–0.1
Comoros	117	2002	125	120	–1	–0.4	117	n.s.	–0.3	115	n.s.	–0.3
Congo	8 000	2003	20 000	12 000	–800	–5.0	8 350	–365	–3.6	8 000	–70	–0.9
Côte d'Ivoire	9 940	2000	30 200	20 100	–1 010	–4.0	9 940	–1 016	–6.8	9 900	–8	–0.1
Dem. Rep. of the Congo	19 600	2000	63 700	30 800	–3 290	–7.0	19 600	–1 120	–4.4	19 500	–20	–0.1
Djibouti	1 000	1985	1 000	1 000	0	0	1 000	0	0	1 000	0	0
Egypt	512	2002	500	500	0	0	500	0	0	500	0	0
Equatorial Guinea	25 700	1995	26 700	26 000	–70	–0.3	25 300	–70	–0.3	25 000	–60	–0.2
Eritrea	6 400	1997	6 700	6 500	–20	–0.3	6 400	–10	–0.2	6 400	0	0
Gabon	152 940	2000	218 500	185 800	–3 270	–1.6	152 940	–3 286	–1.9	150 000	–588	–0.4
Gambia	58 100	2000	70 400	61 200	–920	–1.4	58 100	–310	–0.5	58 000	–20	n.s.
Ghana	13 729	2000	18 000	16 800	–120	–0.7	13 800	–300	–2.0	12 400	–280	–2.1
Guinea	276 342	1997	299 200	279 200	–2 000	–0.7	276 200	–300	–0.1	276 000	–40	n.s.
Guinea-Bissau	248 400	1990	276 000	248 400	–2 760	–1.1	221 000	–2 740	–1.2	210 000	–2 200	–1.0
Kenya	52 980	1982	54 700	52 000	–270	–0.5	50 000	–200	–0.4	50 000	0	0
Liberia	9 244	2000	19 300	14 300	–500	–3.0	9 250	–505	–4.3	6 750	–500	–6.1
Madagascar	303 814	2004	330 000	330 000	0	0	315 000	–1 500	–0.5	300 000	–3 000	–1.0
Mauritania	104	1993	150	110	–4	–3.1	100	–1	–1.0	100	0	0
Mauritius	120	2004	45	70	3	4.5	90	2	2.5	120	6	5.9
Mayotte	668	1989	670	670	0	0	670	0	0	670	0	0
Mozambique	392 749	1997	402 500	396 200	–630	–0.2	391 800	–440	–0.1	390 200	–320	–0.1
Nigeria	997 700	1995	999 000	998 000	–100	n.s.	997 000	–100	n.s.	997 000	0	0
Sao Tome and Principe	n.a.	n.a.										
Senegal	127 702	2000	169 000	145 000	–2 400	–1.5	127 000	–1 800	–1.3	115 000	–2 400	–2.0
Seychelles	2 900	1960	2 500	2 500	0	0	2 500	0	0	2 500	0	0
Sierra Leone	105 300	2000	167 700	145 400	–2 230	–1.4	105 300	–4 010	–3.2	100 000	–1 060	–1.0
Somalia	10 000	1975	9 500	8 600	–90	–1.0	7 800	–80	–1.0	7 300	–100	–1.3
South Africa	3 054	1999	3 500	3 500	0	0	3 050	–45	–1.4	3 000	–10	–0.3
Sudan	500	1995	500	500	0	0	500	0	0	500	0	0
Togo	1 094	2000	1 000	1 000	0	0	1 000	0	0	1 000	0	0
United Rep. of Tanzania	127 200	2000	152 000	140 000	–1 200	–0.8	127 200	–1 280	–1.0	125 000	–440	–0.4
Africa	**3 242 754**	**1997**	**3 670 190**	**3 427 520**	**–24 267**	**–0.68**	**3 217 957**	**–20 956**	**–0.63**	**3 160 105**	**–11 570**	**–0.36**

Note: n.a. = not available; n.s. = not significant.

economies and local livelihoods. They represent a significant, traditional source of wood (timber, fuelwood and charcoal) and tannins, and they support the fisheries of local populations. Notwithstanding these benefits, the rapid growth of human populations and the resulting pressure on coastal environments often lead to uncontrolled exploitation (especially in Cameroon and Guinea), posing severe threats to the mangroves.

According to the results of the current assessment, Africa has lost about 500 000 ha of mangroves over the last 25 years (Figure 6) (or about 13.8 percent of the 1980 extent), with the major losses occurring in Gabon, Sierra Leone, Guinea-Bissau, Senegal and the Democratic Republic of the Congo.[1] Conversion of land for rice production and coastal infrastructure, and to a lesser extent cutting of wood for poles and for fuelwood – used for drying fish, making salt and cooking – are among the main causes of this loss.

In relative terms, Côte d'Ivoire and Liberia have been identified as the countries with the highest negative annual rate of change. Commercial exploitation and the massive urbanization in Côte d'Ivoire have been identified as the main causes of this annual change, which is the highest in the region (–4.4 percent for the period 1980–2005). In Liberia, uncontrolled urbanization and extensive felling caused a loss of –4.1 percent over the last 25 years.

On the other hand, the successful plantation programme begun in the 1980s in Mauritius has led to an increase in the extent of mangrove area in this country, which nearly balanced the considerable previous net loss from the high demand for fuelwood and infrastructure development. According to recent surveys, the extent of mangroves may continue to increase in the future. Increased awareness of the uses and benefits of mangroves in the region is leading to other small successes in conservation, reforestation and sustainable use of these coastal ecosystems. In Eritrea, recent small-scale afforestation activities helped in the stabilization of mangrove extent; in Kenya, the 1982 presidential ban on commercial exploitation of mangrove poles helped slow the rate of impoverishment of this national resource; in Sierra Leone, efforts were made to rehabilitate degraded sites and control the exploitation of mangroves for fuelwood for fish smoking in the late 1980s and early 1990s; in the Congo, several activities and initiatives are raising awareness of the importance of sustainable management of these coastal ecosystems as a source of food security for local populations and of their restoration in already degraded sites; educational activities are being undertaken in the Gambia, Seychelles and South Africa.

A few countries showed no major changes in their mangrove area since the 1980s. However, in the case of Djibouti, Mayotte, Seychelles and Togo, this apparent success may be due to a lack of recent, reliable quantitative information. In some other countries, even though the extent of forests has effectively remained constant, camel browsing or other threats or uses have seriously compromised the health and quality of the stands (e.g. in Egypt and the Sudan).

MAIN USES AND THREATS

Mangroves have been used for generations as a source of wood, medicine and food. Rural communities in West Africa extract fuelwood, timber for houses and boat construction, and wood for charcoal. A large number of non-wood forest products, such as tannins, medicines, beverages and natural pesticides (*Laguncularia racemosa* leaves, mostly used in Guinea) are also collected in mangrove forests. Food security in these countries is closely linked to these coastal forests in which local people collect shrimp, oyster and other species of shellfish. Subsistence and commercial fisheries, which are traditional activities in several countries, depend on healthy mangroves.

[1] Countries listed in order of size of losses.

FIGURE 5
Africa – five countries with the largest mangrove area, 2005

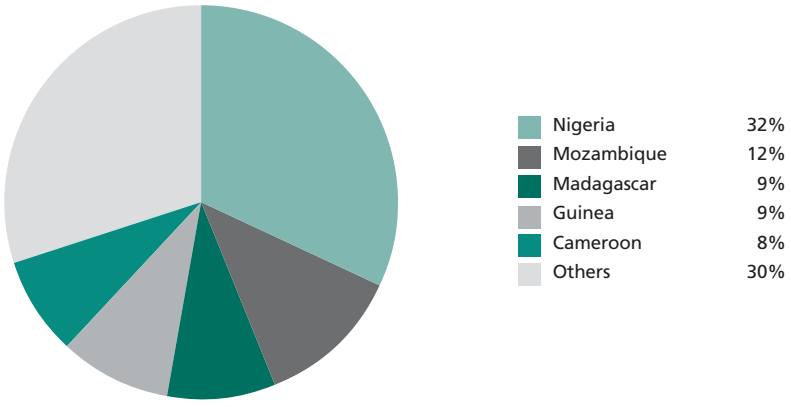
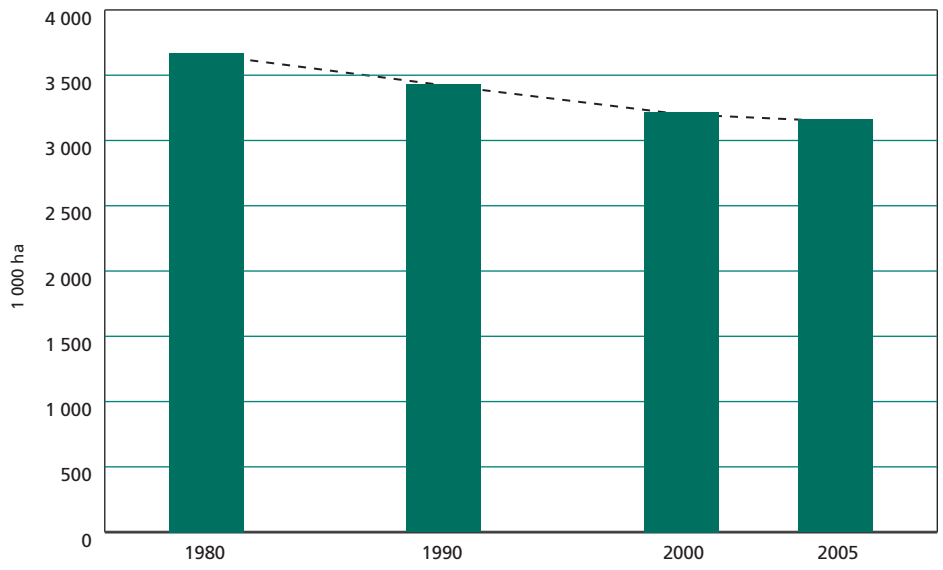


FIGURE 6
Africa – mangrove area changes, 1980–2005



During the past decades, substantial areas of mangrove in West Africa have been converted to other land uses such as the production of salt and rice. The shrimp-farm industry has been less developed than in other regions, but a few countries have undertaken this activity (e.g. Guinea). Other causes of mangrove loss on this coast are the overexploitation of resources and urban and tourism development. In contrast, awareness of the services and benefits provided by mangroves is growing in most western African countries. Despite this positive note, mangroves in West and Central Africa still have to face major threats, particularly the ever-increasing human pressure on coastal lands (e.g. Cameroon, Guinea and Sierra Leone), the lack of sustainable resource management (e.g. the Congo), and the absence of adequate legislation for mangrove protection (e.g. Cameroon). Pollution is also an increasing threat in several countries (Cameroon, Democratic Republic of the Congo and Ghana).

In eastern Africa, mangroves are mainly used for production of charcoal and fuelwood, construction of huts and boats, and collection of non-wood forest products such as tannins, leaves (used as fodder for animals), shellfish, honey and medicines. Fisheries industries, such as those in Madagascar, Mozambique and the United Republic of Tanzania, depend on mangrove health for their productivity. Oil and solid pollution are significant problems along this coast, owing to the proximity of industries and oil terminals and the related heavy maritime traffic. Mangroves have also been converted to other land uses – mainly for tourism and urban development – even though the east coast has a smaller mangrove area than the west.

In arid and semi-arid countries, browsing of mangroves by camels (and in some countries cattle and goats) is the main threat. It negatively affects the health and quality of the stands by limiting tree growth and regeneration, but may leave the total extent of the forest unchanged.

MANGROVE CONSERVATION AND MANAGEMENT

Adequate legislation to protect and conserve mangrove forests is lacking in most African countries. The United Republic of Tanzania, where all mangroves are legally protected, but also the Congo, Egypt, Kenya, Seychelles and South Africa are exceptions. Notwithstanding the lack of legal protection, consciousness of the services and benefits provided by mangroves is growing, and an increasing number of initiatives are being undertaken to rehabilitate and protect local forests. Educational activities are also being launched in a number of countries (the Congo, Eritrea, the Gambia, Seychelles and South Africa among others).

Mangrove afforestation and reforestation of previously cleared areas have been undertaken in this region, but these activities have often been developed only at the community level. Some examples can be found in Benin, Eritrea, Guinea, Mauritius and Sierra Leone. In Mauritius, reforestation programmes were begun in the early 1980s and continue today, steadily increasing the national mangrove area. Natural expansion of mangroves is very rare in Africa. The literature reports some evidence of this process only in the Comoros.

Chapter 5
Asia

VEGETATION AND SPECIES COMPOSITION

Asia has 25 countries with mangroves under a wide range of climatic conditions, from arid (the Arabian peninsula) to subtropical (China, Japan) to humid tropical (Southeast Asia). The considerable length of the coastlines and the multitude of islands, sheltered bays, alluvial flats, deltas and estuaries make this region a perfect habitat for mangrove development.

Asia has the largest mangrove area of any region, and the mangroves are exceptional for their high biodiversity (especially in South and Southeast Asia). As reported in Table 7, more than 50 mangrove species (the highest mangrove species diversity in the world) grow along its coasts, some of which (*Aegiceras floridum, Camptostemon philippinensis, Heritiera globosa*) are endemic to the region. Some of the species, even though relatively common in some countries, are considered rare in the region as a whole (e.g. *Ceriops decandra, Osbornia octodonta, Scyphiphora hydrophyllacea, Sonneratia ovata*). *Kandelia candel* is an interesting case: it is found as far north as Japan and is a common species in Hong Kong, but appears to be truly rare in Southeast Asia (FAO, 2006a).

The edaphic and coastal features of South and Southeast Asian countries, together with the high rainfall and significant riverine inputs, are particularly favourable to the development of well-structured mangrove forests. Along these coasts, trees may grow to a height of 20–30 m in Bangladesh, India, Malaysia or Thailand, or even to 50 m in Indonesia. This country harbours the highest biodiversity in the region – and in the world – with 43 different true mangrove species, followed by Malaysia and Australia. Other countries, such as New Zealand, Oman and Qatar, have only one mangrove species growing along their coasts.

Some of the largest mangrove forests in the world are found in Asia, the most well-known being the Sundarbans, a transboundary forest covering approximately 1 million hectares in Bangladesh and India. Some 60 percent of this forest is found in Bangladesh, where it is protected in the Sundarbans Reserved Forest, which is both a Ramsar site, since 1992, and a World Heritage site of the United Nations Educational, Scientific and Cultural Organization (UNESCO) since 1997. The creation of the reserve began in 1875, with some 542 000 ha legislated for protection. The physical boundary changed several times over the years, but definition of the protected area ended in 1932/1933 and since then the boundary has not changed. The remaining part is protected in the Sundarbans National Park in India (a UNESCO World Heritage site since 1987). The Indian Sundarbans, even though very rich in species, has a lower complexity and structure in comparison with the Bangladesh section, probably due to higher salinity.

The Matang Mangrove Forest Reserve, peninsular Malaysia, is another large forest in the region. This mangrove area is commonly known as the best-managed mangrove forest in Malaysia and among the best-managed worldwide. Sustainable production of fuelwood and poles from almost all the mangrove area began in 1902–1904, and the entire reserve came under intensive management by the Perak State Forest Department in 1908 (FAO and Wetlands International, 2006).

An example of a pristine and well-managed mangrove forest can be found in Ranong, Thailand (some 600 km southwest of Bangkok), a narrow coastal plain characterized by many waterways and well-structured mangrove forests, designated in 1997 as a Biosphere Reserve of UNESCO's Man and the Biosphere Programme. The people

TABLE 7
Mangrove species composition in Asian countries

Species	Bahrain	Bangladesh	Brunei Darussalam	Cambodia	China	India	Indonesia	Iran	Japan	Kuwait	Malaysia	Maldives	Myanmar	Oman	Pakistan	Philippines	Qatar	Saudi Arabia	Singapore	Sri Lanka	Thailand	Timor-Leste	UAE	Viet Nam	Yemen
Acanthus ebracteatus			√		√		√				√					√			√		√			√	
Acanthus ilicifolius		√	√		√	√	√				√		√			√			√	√	√	√		√	
Acanthus xiamenensis					√																				
Acrostichum aureum		√	√		√	√	√		√		√	√[a]	√			√			√	√	√	√		√	
Acrostichum speciosum			√		√		√				√		√			√			√		√				
Aegialitis annulata							√																		
Aegialitis rotundifolia		√				√							√								√				
Aegiceras corniculatum		√	√		√	√	√				√		√		√	√			√	√	√	√		√	
Aegiceras floridum							√				√					√								√	
Avicennia alba		√	√	√		√	√				√		√			√			√		√			√	
Avicennia marina	√	√	√	√	√	√	√	√	√	√[b]	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Avicennia officinalis		√	√	√		√	√				√		√			√			√	√	√			√	
Avicennia rumphiana[c]							√				√					√			√						
Bruguiera cylindrica			√		√	√	√				√	√	√			√			√	√	√			√	
Bruguiera exaristata							√																		
Bruguiera gymnorrhiza		√	√	√	√	√	√		√		√	√	√			√			√	√	√			√	
Bruguiera hainesii							√				√														
Bruguiera parviflora			√			√	√				√		√			√			√		√	√		√	
Bruguiera sexangula		√	√	√	√	√	√				√	√	√			√			√	√	√			√	
Bruguiera sexangula var. *rhyncopetala*					√																				
Camptostemon philippinensis							√									√									
Camptostemon schultzii							√																		
Ceriops decandra		√		√		√	√				√		√			√				√	√			√	
Ceriops tagal		√	√	√	√	√	√				√	√	√		√				√	√	√			√	
Cynometra iripa											√										√				
Cynometra ramiflora						√					√								√		√				
Excoecaria agallocha		√	√	√	√	√	√		√		√	√	√			√			√	√	√	√		√	
Excoecaria indica		√					√				√								√		√				
Heritiera fomes		√				√							√								√				
Heritiera globosa			√				√				√														
Heritiera kanikensis						√																			
Heritiera littoralis		√	√		√	√	√		√		√	√	√			√			√	√	√	√		√	
Kandelia candel		√	√		√	√	√		√		√		√			√			√		√			√	
Lumnitzera littorea			√	√	√		√				√		√			√			√		√			√	
Lumnitzera racemosa			√	√	√	√	√		√		√	√	√			√			√	√	√	√		√	
Nypa fruticans		√	√	√	√		√		√		√		√			√			√	√	√			√	
Osbornia octodonta							√				√					√									
Pemphis acidula					√		√		√		√	√				√			√	√					
Rhizophora x *annamalayana*						√																			
Rhizophora apiculata		√	√	√	√	√	√				√	√	√			√			√	√	√	√		√	

TABLE 7 (continued)
Mangrove species composition in Asian countries

Species	Bahrain	Bangladesh	Brunei Darussalam	Cambodia	China	India	Indonesia	Iran	Japan	Kuwait	Malaysia	Maldives	Myanmar	Oman	Pakistan	Philippines	Qatar	Saudi Arabia	Singapore	Sri Lanka	Thailand	Timor-Leste	UAE	Viet Nam	Yemen
Rhizophora x *lamarckii*						√					√					√									
Rhizophora mucronata		√	√	√	√	√	√	√			√	√	√		√	√		√	√	√	√		√		√
Rhizophora stylosa					√	√	√		√		√					√			√					√	
Scyphiphora hydrophyllacea			√		√	√	√				√					√			√	√				√	
Sonneratia alba			√	√	√	√	√		√		√		√			√			√	√	√	√		√	
Sonneratia apetala		√				√							√							√	√				
Sonneratia caseolaris		√	√	√	√	√	√				√	√	√			√			√	√	√			√	
Sonneratia griffithii						√					√		√								√				
Sonneratia x *gulngai*			√				√																		
Sonneratia hainanensis					√																				
Sonneratia ovata			√		√		√				√					√			√		√			√	
Sonneratia x *urama*							√																		
Xylocarpus granatum		√	√	√	√	√	√				√		√			√			√	√	√	√		√	
Xylocarpus mekongensis		√				√	√				√		√			√			√		√				
Xylocarpus rumphii							√				√	√				√									
Total no. of species	**1**	**23**	**28**	**16**	**28**	**32**	**43**	**2**	**11**	**1**	**41**	**14**	**29**	**1**	**4**	**35**	**1**	**2**	**32**	**22**	**34**	**11**	**2**	**27**	**2**

[a] Uncertain.
[b] Introduced species.
[c] Also referred to as *Avicennia lanata*.

living in the reserve depend primarily on fishing and shrimp farming. Ecotourism is increasing slowly, also owing to the presence and activities of the Ranong Mangrove Research Centre, which has a long history of scientific research in this area, with several research workers and students visiting yearly.

The delta of the Ayeyarwady River, Myanmar, is another large mangrove forest, which has, however, been degraded over time owing to overexploitation of the resource and to the conversion of land for rice fields, an activity promoted by the government as a way to ensure self-sufficiency in food production.

Other important forests in the region are found in Irian Jaya, Kalimantan and Sumatra in Indonesia, which is the country with the greatest extent of mangroves globally.

In western Asia and the Near East, the weather conditions are more arid, reducing biodiversity and forest complexity. Mangroves grow mainly as narrow stands in tidal areas, in seasonal river mouths and on off-shore islands, often represented by monospecific stands of *Avicenna marina* or *Rhizophora mucronata*. Coastal mangrove ecosystems are not present on the small Iraqi coastline and in Kuwait grow only as introduced species. Here experimental forests were planted to study the adaptability and growth performance of *Avicennia marina* in the harsh and extreme conditions of aridity and salinity.

MANGROVE RESOURCES: STATUS AND TRENDS 1980–2005

The mangrove area in Asia equals more than 5.8 million hectares and accounts for some 38 percent of global mangrove area, representing the highest percentage of mangroves worldwide (Table 8).

TABLE 8
Status and trends in mangrove area – Asia (1980–2005)

Country/ area	Most recent reliable estimate		1980	1990	Annual change 1980–1990		2000	Annual change 1990–2000		2005	Annual change 2000–2005	
	ha	Ref. year	ha	ha	ha	%	ha	ha	%	ha	ha	%
Bahrain	100	1992	150	100	–5	–4	90	–1	–1.0	90	0	0
Bangladesh	476 215	1995	428 000	460 000	3 200	0.7	476 000	1 600	0.3	476 000	0	0
Brunei Darussalam	18 418	1996	18 400	18 400	0	0	18 400	0	0	18 400	0	0
Cambodia	72 835	1997	91 200	82 400	–880	–1.0	73 600	–880	–1.1	69 200	–880	–1.2
China	22 480	2001	34 157	28 344	–581	–1.8	22 955	–539	–2.1	22 480	–95	–0.4
India	446 100	2003	506 700	467 000	–3 970	–0.8	448 200	–1 880	–0.4	448 000	–40	n.s.
Indonesia	3 062 300	2003	4 200 000	3 500 000	–70 000	–1.8	3 150 000	–35 000	–1.0	2 900 000	–50 000	–1.6
Iran, Islamic Republic of	19 234	1997	27 500	22 500	–500	–2.0	19 100	–340	–1.6	19 000	–20	–0.1
Japan	800	2005	800	800	0	0	800	0	0	800	0	0
Kuwait	5	2004	n.s.	n.s.	n/a	n/a	n.s.	n/a	n/a	5	n/a	n/a
Malaysia	564 971	2005	674 000	642 000	–3 200	–0.5	589 500	–5 250	–0.8	565 000	–4 900	–0.8
Maldives	n.a.	n.a.	n.a.	n.a.	n/a	n/a	n.a.	n/a	n/a	n.a.	n/a	n/a
Myanmar	518 646	1999	555 500	536 100	–1 940	–0.3	516 700	–1 940	–0.4	507 000	–1 940	–0.4
Oman	1 088	1995	2 000	2 000	0	0	1 000	–100	–6.7	1 000	0	0
Pakistan	158 000	2001	345 000	207 000	–13 800	–5.0	158 000	–4 900	–2.7	157 000	–200	–0.1
Philippines	247 362	2003	295 000	273 000	–2 200	–0.8	250 000	–2 300	–0.9	240 000	–2 000	–0.8
Qatar	500	1992	500	500	0	0	500	0	0	500	0	0
Saudi Arabia	20 400	1985	21 000	20 000	–100	–0.5	20 000	0	0	20 000	0	0
Singapore	500	1990	1 790	500	–129	–12.0	500	0	0	500	0	0
Sri Lanka	9 530	1996	9 600	9 300	–30	–0.3	9 000	–30	–0.3	8 800	–40	–0.4
Thailand	244 085	2000	280 000	250 200	–2 980	–1.1	244 100	–610	–0.2	240 000	–820	–0.3
Timor-Leste	1 802	2000	4 250	3 000	–125	–3.4	1 800	–120	–5.0	1 800	0	0
United Arab Emirates	4 000	1999	3 500	3 800	30	0.8	4 000	20	0.5	4 100	20	0.5
Viet Nam	157 500	2000	269 150	213 500	–5 565	–2.3	157 500	–5 600	–3.0	157 000	–100	–0.1
Yemen	927	1993	1 000	950	–5	–0.5	900	–5	–0.5	900	0	0
Asia	**6 047 798**	**2002**	**7 769 197**	**6 741 394**	**–102 780**	**–1.41**	**6 162 645**	**–57 875**	**–0.89**	**5 857 575**	**–61 014**	**–1.01**

Note: n.a. = not available; n/a = not applicable; n.s. = not significant.

As reported in Figure 7, Indonesia is the country with the largest extent of mangroves in the region (and in the world), accounting for about half the regional extent of mangrove area. Other Asian countries with a significant extent of mangroves are (in order of mangrove area) Malaysia, Myanmar, Bangladesh and India, which, together with Indonesia, account for more than 80 percent of total Asian mangrove area. The mangroves of these five countries also represent a high percentage of global mangrove extent – all of them are included in the ten countries with the largest extent of mangrove area worldwide (Figure 3, page 12).

Mangroves in these five countries have experienced intensive logging or conversion to other land uses (e.g. shrimp ponds or rice paddies), and the majority of them are no longer pristine. Human pressure on coastal areas and increasing demand for land for agriculture represent increasing threats to mangroves in these countries. However, in several localities they still form dense and well-structured ecosystems.

In this region some 1 900 million hectares of mangroves – or about 25 percent of the 1980 area – have been lost during the last 25 years (Figure 8). More than 90 percent of this loss has been caused by the major mangrove area changes in Indonesia, Pakistan, Viet Nam, Malaysia and India, which experienced a cumulative loss of more than

FIGURE 7
Asia – five countries with the largest mangrove area, 2005

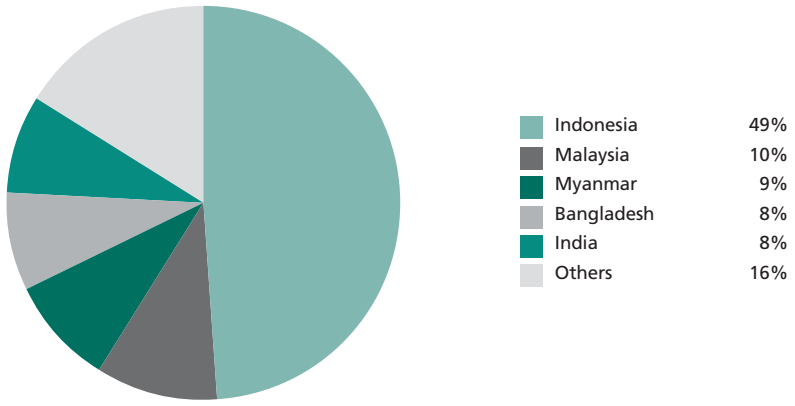
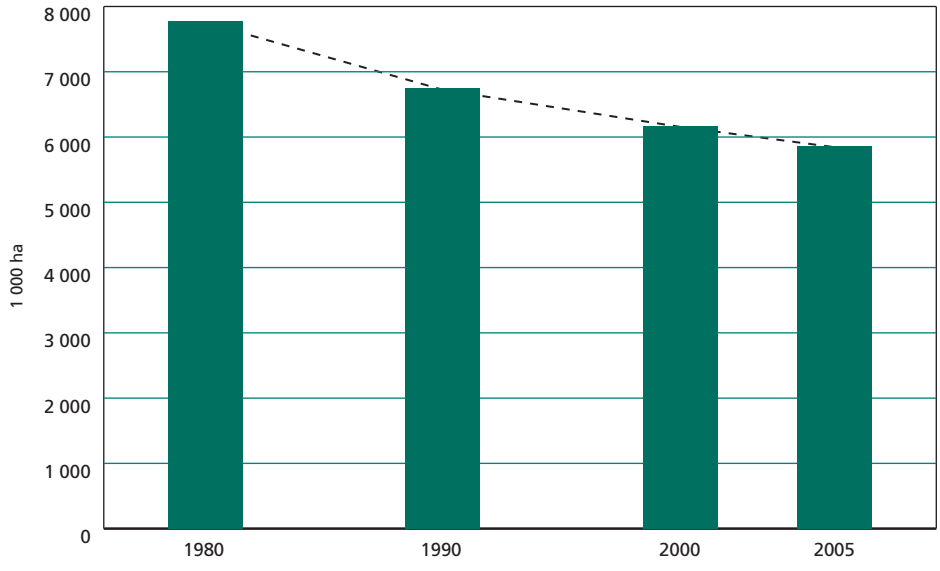


FIGURE 8
Asia – mangrove area changes, 1980–2005



1 700 million hectares. The main causes of mangrove loss in Indonesia are conversion of land for shrimp farms (East Java, Sulawesi and Sumatra), excessive logging and, to a lesser extent, conversion of land to agriculture or salt pans (Java and Sulawesi). Other areas have been degraded by oil spills (East Kalimantan) and pollution. In Pakistan mangrove forests have been intensively used for fuelwood, poles, fodder and camel grazing. Overexploitation of these resources has led to the loss of nearly 190 000 ha. Industrial pollution and increasing salinity due to dam construction constitute other threats.

Malaysia lost about 110 000 ha of mangroves from 1980 to 2005. During the first decade (1980–1990), mangrove losses were primarily due to conversion of land for agriculture, shrimp ponds or urban development. Shrimp farming spread very quickly in the country, especially in peninsular Malaysia, leading to the clearing of large areas of forest.

However, awareness of the services and benefits provided by mangroves is growing and even though much remains to be done, conservation and restoration are being undertaken in many countries. For example, in 1990 a collaboration between the Government of Pakistan and the World Conservation Union (IUCN) facilitated the rehabilitation of 19 000 ha of *Avicennia marina* and *Rhizophora mucronata*. In 1999 about 17 000 ha were restored in the Indus delta thanks to the support of the World Bank.

Viet Nam is making a considerable effort to restore its forests; afforestation activities began in 1975, after the unification of the country, and were expanded in the early 1990s, when the Government of Viet Nam rehabilitated nearly 53 000 ha of mangroves. Various national and external NGOs have also supported rehabilitation projects, totalling some 14 000 ha of mangrove plantation in various provinces in the last decade. The success of rehabilitation efforts in Viet Nam is mainly due to the close cooperation between funding agencies, local authorities, the government and the people.

Even if the regional results indicate a major loss of mangroves over the past two decades (1980–2005), some countries, such as Brunei Darussalam, Japan, Qatar and Saudi Arabia, experienced limited or no significant change in the extent of their mangrove forests. In Brunei Darussalam, the lack of human pressure and the consequent low demand for wood products from the mangroves has left these forests virtually pristine, representing some of the best-preserved mangroves in Southeast Asia. In Japan natural regeneration and human-made reforestation have balanced the few changes occurring in the country due to traditional mangrove use, while in Qatar wood products are rarely extracted from mangroves. For Saudi Arabia, however, the status quo may be only apparent, since, even if only a very limited extent of mangroves has been lost, several sites have been degraded due to intensive camel grazing and oil pollution.

In the last five years, Bahrain, Oman, Singapore, Timor-Leste and Yemen have succeeded in slowing the negative trend in area changes. The modifications in resource management in Oman, for example, have helped reduce the negative annual change rate of the 1990s to zero. In the 1980s, Singapore experienced a relatively significant mangrove net loss rate, owing to the high demand for fuelwood and charcoal and to urban and shrimp-farm development. However, major efforts have resulted in conservation of the remaining area during the last ten years (1995–2005).

Positive change rates are found in Bangladesh, the United Arab Emirates and – although with only a limited mangrove area – Kuwait. These countries jointly reported an increase in extent of mangrove area of some 48 000 ha since 1980.

MAIN USES AND THREATS

Rural populations in Asia have traditionally used mangroves as a source of wood and non-wood forest products for the production of charcoal, fuelwood, and timber and poles for houses, boats and fish-traps. In Indonesia, for example, the commercial exploitation of mangrove wood has a long history, and has been important particularly for the production of wood chips, timber (now banned) and charcoal, including for export. In addition, poles extracted from the Rhizophoraceae are used for building foundations. Malaysia has a long tradition of production of mangrove charcoal for national and international markets.

Besides these exceptions, mangroves have generally been used for local needs. *Nypa fruticans* is a common species in most Asian countries, and it has often been used as thatching material for houses in Bangladesh, Brunei Darussalam, India, Indonesia, Malaysia, the Philippines and Viet Nam. Several fishing and rural communities depend on the fish and shellfish in mangroves as a source of income and food security; when mangrove forests are destroyed, a significant decrease in local fish catches may result. Indonesia, the Philippines and Thailand have major offshore fisheries, which represent a significant portion of national income and depend partly on mangroves.

Many rural communities have used mangroves to produce honey, tannins and traditional medicines. Ecotourism activities are increasing in the region, providing further sources of sustainable income to local populations and creating awareness of the services and benefits provided by mangroves.

Mangrove leaves are often used as fodder for camels, goats and sheep in the Near East, where mangroves are often the only coastal forest resource. However, overexploitation of the trees for this use may reduce mangrove growth and density, stunting trees and degrading stand quality. When the outer trees are overused, it is common practice to provide fresh, additional fodder for camels by opening the way to the inner mangroves. In some places this practice has affected the quality of the stand even if the mangrove area was not reduced significantly.

The main causes of loss of area in Asia have been overexploitation and the development of shrimp farms. Because of its high economic return, shrimp farming has been promoted to boost national economies, as a potential source of income for local communities and as a means of poverty alleviation. However, this activity may cause loss of habitat and of ecosystem services provided by mangroves, and may damage surrounding areas through pollution caused by the chemical products used.

In some countries (e.g. India and Myanmar) government policies have promoted self-sufficiency in food production through the conversion of mangrove lands to rice paddies, while in other countries (e.g. China, Indonesia, the Philippines and Viet Nam) mangrove areas have been used for salt production. In addition, some mangrove areas have been clear-cut for urban or tourist development or converted to agriculture. The decrease in freshwater input or the interruption of flows caused by the construction of dams and diversion of water for irrigation may increase soil salinity, damaging the surrounding mangroves, as has occurred in Singapore and Pakistan.

During the Viet Nam war (1962–1972), mangrove forests often served as bases for military operations, and were consequently highly damaged by chemical warfare (herbicides and napalm). Further losses have been caused by the conversion of mangrove land to other uses such as shrimp ponds, agriculture, salt pans and human settlements.

Among the current threats to mangrove ecosystems, the ever-increasing human pressure on coastal areas is one of the most serious. In addition to human-induced threats, natural hazards such as cyclones, storms and floods frequently occur in this region, threatening several coastal ecosystems, including mangroves. Trees in the front lines are often uprooted and damaged during these events. However, the loss of this 'sacrificial belt' (Takle, 2007) may contribute to the overall protective function of dense forests, as occurred during the cyclone in Orissa, India, in 1999. It is also reported that many people in Bangladesh were protected by mangroves during the tidal wave that hit the Chakaria Sundarbans in 1960 (which at that time was still covered by dense forests), and in Viet Nam, when typhoon Wukong hit three northern provinces in 2000, but left no damage to the dykes behind the regenerated mangroves (see 'Functions and uses of mangroves', page 4).

MANGROVE CONSERVATION AND MANAGEMENT

Threats to and losses of mangroves in Asian countries are still a problem, However, awareness of the importance of mangroves is growing also in this region, and several afforestation and rehabilitation efforts are being undertaken, especially for protection and conservation purposes.

The increasing well-being of many countries in the Near East – especially of those overlooking the Persian Gulf and the Straits of Hormuz – is alleviating the pressure on these ecosystems. On the other hand, the negative effect of this rapid economic growth is represented by the increased solid, industrial and oil pollution, which may threaten local flora and fauna, potentially leading to the death of mangrove trees (e.g. *Avicennia marina* in Qatar).

Bangladesh, Malaysia and Viet Nam have very long traditions of sustainable management, plantation and afforestation programmes in mangroves. Mangrove management and protection in Bangladesh, for example, started at the beginning of the twentieth century, with the preparation of forest management working plans and the creation of what is now called the Sundarbans Reserved Forest. Coastal afforestation programmes started in 1966, involving several districts.

Planting may be undertaken for production (wood and non-wood forest products), for environmental and/or for educational purposes (e.g. the Ishigaki and Iriomote islands of Japan). Experimental plantations have also been established successfully in extremely arid countries such as Bahrain, Kuwait and the United Arab Emirates. Many countries in Asia have been increasingly promoting establishment and maintenance of mangrove greenbelts as protection against natural hazards, especially those countries affected by destructive typhoons each year (e.g. the Philippines and Viet Nam). In China, strip forests, primarily of *Kandelia candel,* were reported to be effective in reducing the breaching and erosion of dykes during cyclones (Su Chunyu, unpublished, 2004). Other protection plantation activities are being undertaken in Bangladesh, Brunei Darussalam, India, Indonesia and Viet Nam.

Many countries have promulgated laws and regulations to protect remaining mangrove areas and mitigate widespread loss. Effective enforcement of this legislation is, however, often hampered by a lack of financial and human resources. Several Asian countries have ratified the Ramsar Convention on Wetlands (2004) and have designated mangrove areas as Ramsar sites or as national parks, reserves and wildlife sanctuaries.

Chapter 6

North and Central America

VEGETATION AND SPECIES COMPOSITION

In North and Central America mangroves are quite widespread along the coasts of 34 countries and areas, ranging from Barbados in the north to Panama in the south, and including several Caribbean islands. The low-island mangroves growing in the territory of Bermuda are among the northernmost communities in the world (32°20′N).

In this region, mangroves constitute a wide range of community types. In the Caribbean they are found growing along the margins of brackish and saline ponds, as fringe communities along the coasts or even inland. 'Overwash' mangrove communities (i.e. communities subject to tidal inundation, exposed to open waters and living on small islands that are entirely inundated with each tidal cycle) are found in Puerto Rico and on offshore cays of Belize and Jamaica. Estuarine mangroves are found only in countries with a rich riverine system, such as the Dominican Republic, Saint Lucia and Trinidad and Tobago. In these countries, mangrove trees may reach considerable heights. Surprisingly, in Anguilla, a low-lying limestone island where mangroves occur on the margin of saline ponds, *Rhizophora mangle* and *Avicennia germinans* may reach heights of up to 25 and 20 m respectively; mangrove trees of such height are not common in similar conditions elsewhere. An area of significant importance within this subregion is the Central Mangrove Wetland found in Grand Cayman, which extends for some 4 000 ha and is still almost entirely pristine and protected, in some areas, under the Marine Parks Law. It represents the largest area of inland mangroves in the Caribbean.

The considerable freshwater input from upstream and the high number of tidal flats found in the mainland countries of this region permit a more extensive development of estuarine mangroves. In this subregion, mangroves grow along both the Atlantic and Pacific coasts. Generally the richest and most complex forests are found on the Pacific coast (Costa Rica, for example), while only small and stunted trees, not exceeding 5 m, grow along the Atlantic coast. Some of the best developed mangrove forests in the subregion are the communities growing in the deltas of the Grijalva and Usumacinta Rivers, in Tabasco Province (Mexico), where trees may reach up to 30 m in height; in the Terraba-Sierpe National Park (Costa Rica); in the Bocas del Toro, San Miguel and Chiriqui Gulfs (Panama); and in Belize, where the forest canopy may reach 40 m.

Other mature mangrove forests are found in the Zapata peninsula (Cuba), and in Guatemala (in the estuaries of the Acomé and Paz Rivers and in the Monterrico lagoon). Extensive mangrove forests also cover the southern tip of Florida, where the freshwater coming from Everglades National Park meets the saltwater from the tidal flats, creating a major mangrove estuary system.

Interesting examples of dwarf mangrove communities may be found in a few Central American countries as a response to the high salinity and/or extremely dry conditions; these trees grow to less than 2–3 m (Turks and Caicos Islands) or even to less than 50 cm (Nicoya Gulf, Costa Rica).

Mangrove biodiversity in this region (Table 9), as well as in South America, is quite low compared with that of Asia (only 10 native mangrove species against more than 50 in Asia). The species are more or less evenly distributed over the region, apart from some exceptions such as *Avicennia bicolor, Pelliciera rhizophorae, Rhizophora harrisonii* and *Rhizophora racemosa,* which are found in a few countries only. A distinct element of Asian mangroves, *Nypa fruticans*, has been introduced in Panama.

TABLE 9
Mangrove species composition in North and Central American countries

Species	Anguilla	Antigua and Barbuda	Aruba	Bahamas	Barbados	Belize	Bermuda	British Virgin Islands	Cayman Islands	Costa Rica	Cuba	Dominica	Dominican Republic	El Salvador	Grenada	Guadeloupe	Guatemala	Haiti	Honduras	Jamaica	Martinique	Mexico	Montserrat	Netherlands Antilles	Nicaragua	Panama	Puerto Rico	Saint Kitts and Nevis	Saint Lucia	Saint Vincent and the Grenadines	Trinidad and Tobago	Turks and Caicos Islands	United States	US Virgin Islands
Acrostichum aureum	√	√			√[a]			√		√		√			√	√				√	√	√	√	√	√	√		√	√	√			√	√
Avicennia bicolor										√				√					√						√	√								
Avicennia germinans	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Avicennia schaueriana	√	√						√				√			√	√					√		√	√			√	√	√	√	√	√	√	√
Conocarpus erectus	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Laguncularia racemosa	√	√		√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Nypa fruticans																										√[b]								
Pelliciera rhizophorae										√															√	√								
Rhizophora harrisonii										√												√[a]			√	√					√			
Rhizophora mangle	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Rhizophora racemosa										√															√	√					√			
Total no. of species	**6**	**6**	**2**	**4**	**4**	**4**	**3**	**6**	**4**	**9**	**4**	**6**	**4**	**5**	**6**	**6**	**3**	**4**	**5**	**5**	**6**	**6**	**6**	**6**	**9**	**10**	**4**	**6**	**6**	**6**	**7**	**5**	**6**	**6**

[a] Uncertain.
[b] Introduced.

MANGROVE RESOURCES: STATUS AND TRENDS 1980–2005

More than 2 million hectares of mangroves are currently growing along the coasts of North and Central American countries (Table 10). In the majority of countries and areas, mangroves cover less than 10 000 ha (representing only about 2 percent of the total regional mangrove area) and only eight countries have more than 50 000 ha.

The most extensive mangrove cover in the region is found in Mexico and Cuba (Figure 9), which have more than one-third and about one-quarter of the regional mangrove area, respectively. These two countries have the fifth and the seventh largest extent of mangroves worldwide (see Figure 3). Together with the United States, Panama and the Bahamas, they account for 82 percent of total mangrove area in North and Central America. The remaining 17 percent is spread among 29 countries and areas.

Cuba and Puerto Rico are exceptions to the serious losses and degradations in mangrove area that have taken place over the past two decades in the region. The major plantation programme currently under way in Cuba helped increase the area from 537 400 ha in 1980 to 547 500 ha in 2000. Here mangrove protection legislation has been in force for more than a decade and has recently been enforced more effectively.

A substantive loss of mangrove area (almost 700 000 ha, or about 23 percent of the area present in 1980) occurred in this region over the last 25 years (Figure 10). When this decrease is compared with area changes in other regions, it is second only to that of Asia.

TABLE 10
Status and trends in mangrove area – North and Central America (1980–2005)

Country/ area	Most recent reliable estimate		1980	1990	Annual change 1980–1990		2000	Annual change 1990–2000		2005	Annual change 2000–2005	
	ha	Ref. year	ha	ha	ha	%	ha	ha	%	ha	ha	%
Anguilla	90	1991	90	90	0	0	90	0	0	90	0	0
Antigua and Barbuda	1 175	1991	1 570	1 200	–37	–2.6	850	–35	–3.4	700	–30	–3.8
Aruba	420	1986	420	420	0	0	420	0	0	420	0	0
Bahamas	141 957	1991	180 000	145 000	–3 500	–2.1	140 000	–500	–0.3	140 000	0	0
Barbados	4	2004	30	16	–1	–6.1	7	–1	–7.9	4	–1	–10.6
Belize	78 511	1990	78 500	78 500	0	0	76 500	–200	–0.3	76 000	–100	–0.1
Bermuda	16	1992	17	16	n.s.	–0.6	15	n.s.	–0.6	15	0	0
British Virgin Islands	587	2001	660	630	–3	–0.5	590	–4	–0.6	570	–4	–0.7
Cayman Islands	7 830	1998	8 500	8 000	–50	–0.6	7 700	–30	–0.4	7 600	–20	–0.3
Costa Rica	41 840	2000	63 400	53 400	–1 000	–1.7	41 800	–1 160	–2.4	41 000	–160	–0.4
Cuba	545 805	2003	537 400	541 400	400	0.1	545 500	410	0.1	547 500	400	0.1
Dominica	10	1991	12	10	n.s.	–1.8	10	0	0	9	n.s.	–2.1
Dominican Republic	21 215	1998	34 400	25 800	–860	–2.8	19 400	–640	–2.8	16 800	–520	–2.8
El Salvador	28 000	2004	46 700	35 300	–1 140	–2.8	28 500	–680	–2.1	28 000	–100	–0.3
Grenada	255	1992	295	260	–4	–1.2	230	–3	–1.2	215	–3	–1.3
Guadeloupe	2 950	1997	3 000	2 990	–1	n.s.	2 960	–3	–0.1	2 950	–2	–0.1
Guatemala	17 727	1999	18 600	17 400	–120	–0.7	17 500	10	0.1	17 500	0	0
Haiti	15 000	1988	17 800	15 000	–280	–1.7	14 300	–70	–0.5	13 700	–120	–0.8
Honduras	78 668	2000	152 500	118 400	–3 410	–2.5	78 700	–3 970	–4	67 200	–2 300	–3.1
Jamaica	9 731	1997	12 000	10 700	–130	–1.1	9 700	–100	–1	9 600	–20	–0.2
Martinique	1 840	1998	1 900	1 900	0	0	1 800	–10	–0.5	1 800	0	0
Mexico	882 032	2002	1 124 000	985 600	–13 840	–1.3	885 000	–10 060	–1.1	820 000	–13 000	–1.5
Montserrat	5	1991	5	5	0	0	5	0	0	5	0	0
Netherlands Antilles	1 138	1980	1 140	1 100	–4	–0.4	1 000	–10	–0.9	1 000	0	0
Nicaragua	69 050	1998	103 400	79 300	–2 410	–2.6	65 000	–1 430	–2	65 000	0	0
Panama	174 435	2000	250 000	190 000	–6 000	–2.7	174 400	–1 560	–0.8	170 000	–880	–0.5
Puerto Rico	8 870	2000	7 650	8 300	65	0.8	8 900	60	0.7	9 000	20	0.2
Saint Kitts and Nevis	79	1991	85	80	–1	–0.6	75	–1	–0.6	70	–1	–1.4
Saint Lucia	200	2002	200	200	0	0	200	0	0	200	0	0
Saint Vincent and the Grenadines	51	1991	55	51	n.s.	–0.7	50	n.s.	–0.2	50	0	0
Trinidad and Tobago	7 150	1991	7 500	7 170	–33	–0.4	7 000	–17	–0.2	7 000	0	0
Turks and Caicos Islands	23 600	1988	23 600	23 600	0	0	23 600	0	0	23 600	0	0
United States	197 648	2001	275 000	240 000	–3 500	–1.3	200 000	–4 000	–1.8	195 000	–1 000	–0.5
US Virgin Islands	216	1999	350	320	–3	–0.9	200	–12	–4.6	150	–10	–5.6
North and Central America	**2 358 105**	**2000**	**2 950 779**	**2 592 158**	**–35 862**	**–1.29**	**2 352 002**	**–24 015**	**–0.97**	**2 262 748**	**–17 851**	**–0.77**

Note: n.s. = not significant.

In absolute terms, the biggest area changes took place in Mexico, Honduras, Panama, the United States and the Bahamas. In Mexico, several areas of mangroves have been clear-cut to convert land to aquaculture, agriculture and urban and tourism development. A significant additional area of mangrove forest, yet to be quantified, was lost during the three hurricanes that hit the Mexican coasts in 2005 (Emily, Wilma and Stan). Between 10 000 and 14 000 ha have been lost annually in this country since 1980. In Honduras, the shrimp and salt production industries have been the main cause

FIGURE 9
North and Central America – five countries with the largest mangrove area, 2005

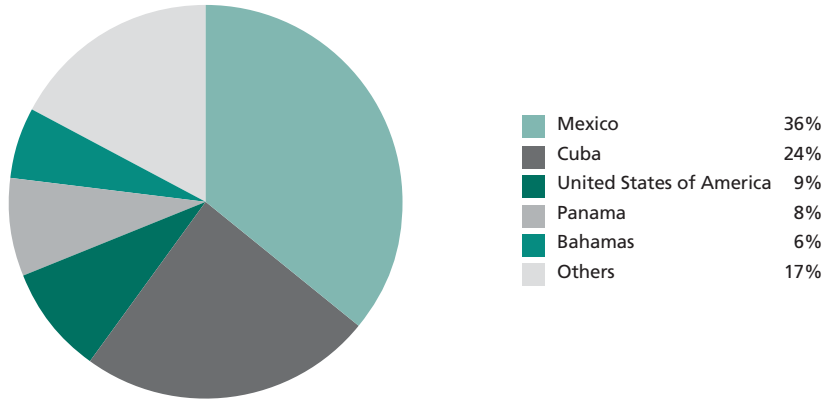
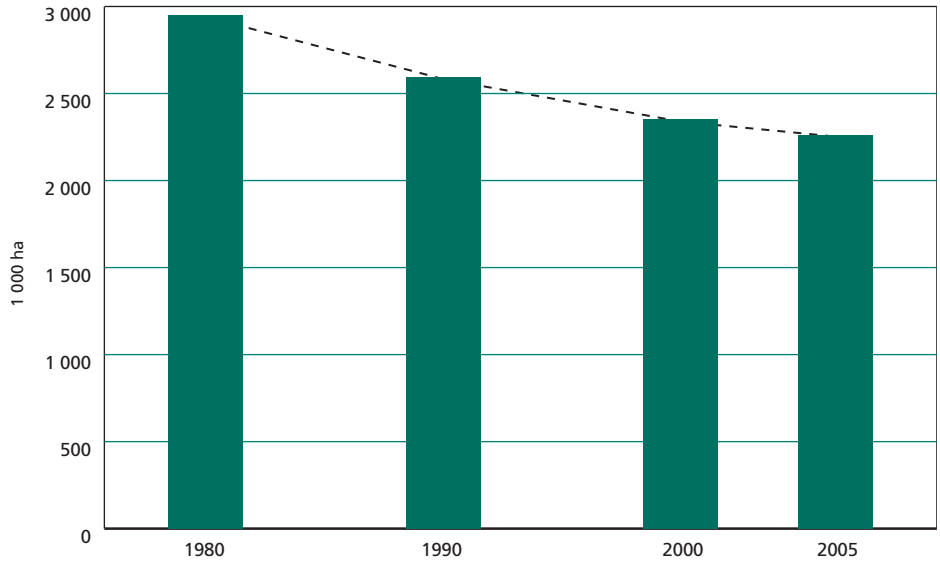


FIGURE 10
Mangrove area changes over time – North and Central America (1980-2005)



of some 85 000 ha of mangroves lost since 1980. Shrimp farms and salt production are also the main cause of the reduced area of mangroves in Panama, which lost a total of 80 000 ha from 1980 to 2005. The use of land for livestock grazing and conversion of mangroves for urban and tourism development are additional causes of mangrove losses. Proper conservation legislation is still lacking in the country, but efforts towards the rehabilitation of degraded areas are being undertaken in a few localities.

In the United States coastal ecosystems have been damaged mainly by drainage for agriculture, reclamation for urban development and canalization. Large mangrove areas now fall within the system of protected areas that forms much of the land and sea area of southern Florida, notably Everglades National Park, and strict laws have been enacted for the protection and/or sustainable utilization of mangroves. In the United States hurricanes also represent a serious threat to mangroves and cause significant losses.

Successful mangrove conservation can be found in the Bahamas, where increased awareness of the services and benefits of mangroves has led to a decline in the annual rate of loss. The 3 500 ha lost annually in the 1980s dropped to 500 ha in the 1990s and to no significant change from 2000 to 2005. Past losses in the country were mainly caused by the development of tourism infrastructure (resorts, marinas and residential areas), opening of access to the waterfront and mosquito control.

Analysing the results in relative terms, the biggest rates of loss (as a percentage of total mangrove area) were recorded from Barbados, the United States Virgin Islands, Honduras, Antigua and Barbuda, the Dominican Republic and El Salvador. The main cause of mangrove degradation and loss in the Caribbean islands has been the rapid and often unsustainable development of tourism industries – on which their economies largely depend – and of the related infrastructure (marinas, hotels and harbours). In Central American countries such as El Salvador, mangroves were lost mainly through uncontrolled urbanization, agricultural encroachment and conversion to shrimp and salt ponds.

As mentioned previously, Cuba and Puerto Rico are the only countries in the region to have experienced a net increase in mangrove area. Cuba has gained about 10 000 ha of mangroves since the 1980s, while Puerto Rico suffered considerable losses during the 1970s, but has recorded an increase in the area of mangroves since the 1980s, probably owing to increased legal protection, natural colonization of new areas and the reversion of agricultural land to its original state as mangrove area. In comparative terms, the increase in area in Puerto Rico (an average annual change of 0.65 percent from 1980 to 2005) is even higher than that in Cuba (0.07 percent).

According to available information, Anguilla, Aruba, Montserrat, Saint Lucia and the Turks and Caicos Islands have maintained their mangrove areas relatively constant over the past 25 years. As a result of increased awareness in the region, the annual rate of mangrove area loss has decreased in the last five years in 24 countries.

MAIN USES AND THREATS

Mangrove resources in North and Central America have traditionally been used for wood and non-wood products, with evidence of human use dating back 5 000 to 6 000 years. They have long been a source of timber for poles and other construction material, charcoal and fuelwood. The collection of crabs, oysters and other molluscs (e.g. *Anadara tuberculosa* and *Anadara similis*) is also a common activity, and in some countries it represents a significant percentage of local – and even national – income. In Cuba, for example, the export of oyster depends mainly on mangrove communities and their health. Villagers also use mangroves to extract tannins and, to a lesser extent, medicines. The nectar of mangrove flowers, particularly *Avicennia* spp., is exploited in the apiculture industry. Beehives are transported to the mangrove areas during flowering to produce honey and wax.

As in other parts of the world, mangroves have been exploited mainly for local use, and commercial exploitation has been practised only in a few cases. These coastal ecosystems provide shelter and breeding grounds for numerous commercial and non-commercial fish species and thus are often used as fishing areas. Panama, for example, has developed a valuable fishing industry that includes a number of fish species dependent on mangroves in at least one phase of their life. Damage to these coastal ecosystems may have significant negative impacts on the fisheries sector. A reduction in the fish catch subsequent to a loss of mangrove area was observed in Jamaica as well as in the United States, where estimated losses of 45–80 percent of mangrove areas south of Miami corresponded to a decline of about 20 percent in the catch of commercial fisheries (Spalding *et al.*, 1997).

Notwithstanding the significant benefits provided by these coastal forests, large areas of mangrove have been cleared over the past decades. Reclamation of land for

urban and tourism development has been the main regional cause of loss over the last 25 years. Drainage and canalization have resulted in an additional loss of mangrove area (e.g. in Barbados). In the Caribbean countries, which are dependent on tourism, a large proportion of the mangroves have been converted for marinas, hotels and residential areas. The severe site modifications undertaken in Barbados, for instance, led to local extinction of *Acrostichum aureum* and *Avicennia schaueriana*, which were originally found in two localities.

Other areas of mangrove forest have been converted to shrimp ponds in Costa Rica, El Salvador, Guatemala and Honduras, even though to a lesser extent than in Asia; to salt paddies; and, in several countries, to agricultural land for rice or pasture for livestock. The conversion of mangrove areas to other land uses was often promoted as a way of strengthening the national economy or improving sanitary conditions. It should be stressed, however, that in some countries (Costa Rica and El Salvador) the conversion of mangrove area to shrimp farming or salt production activities is no longer allowed, but it is still a severe threat to mangroves in others (e.g. Guatemala and Honduras).

In recent years the biggest regional threats to mangroves are the ever-increasing development of the tourism industry, pollution from runoff of fertilizers and pesticides, and improper disposal of wastes. Oil pollution is not a widespread problem for the region as a whole, but it is a serious threat in Panama owing to the extremely high maritime traffic in the Panama Canal (Spalding *et al.*, 1997).

Because of their location in the front line between ocean and land, mangroves also face natural threats such as the frequent hurricanes. In 1989, during hurricane Hugo, dense mangrove forests played a significant role in the protection of lives and resources in the British Virgin Islands, yet some mangrove trees on the ocean side were damaged. During the passage of hurricane Andrew in 1992, trees were uprooted in the Florida Everglades. More recently, the mangroves of the Cayman Islands were severely impacted in 2004 by hurricane Ivan, which caused some US$1.8 billion in damage and significant destruction to the coastal and central mangrove wetlands of Grand Cayman. Studies are under way to assess the impact of and possible damage caused by the recent passage of hurricane Katrina, which devastated the coasts of Alabama, Florida, Louisiana and Mississippi in August 2005 and was recorded as the one of the most destructive natural disasters in the history of the United States.

MANGROVE CONSERVATION AND MANAGEMENT

Local authorities are increasingly recognizing the importance of mangrove forests and the benefits of healthy mangroves, both for their aesthetic and ecological value and for the economic advantages provided by sustainable tourism and by their link with national fisheries, among others. A step forward in the protection of these ecosystems has been the decreased number of shrimp farm permissions issued and the restoration of mangrove forests in some abandoned ponds. Some countries have stressed that the conservation of coastal areas is critical to future socio-economic development, and a series of activities are being organized to increase awareness in the public and private sectors. 'Coastal Awareness Month' – launched in April 2005 in the Bahamas by the Ministries of Education and Tourism and a group of environmentalists drawn from the public and private sectors (the Green Team) – is a good example of such activities.

Mangroves are also increasingly appreciated for their protective role against coastal erosion and other natural hazards. Some governments have initiated activities to conserve and protect them. On the other hand, in some countries in the region the public still does not consider mangroves a resource to be actively protected.

Adequate legislation for the protection and conservation of mangroves is not very common in the region, and only very few countries have specific laws for the conservation of these ecosystems (Costa Rica and the United States are examples). In

some countries such as the Bahamas and Cuba, mangroves are protected under different habitat and/or forest laws, and in others they are often included in wildlife, wetland, coastal or maritime protected areas. Some areas are also included in the Ramsar list: Het Spaans Lagoen (Aruba), Terraba-Sierpe National Park (Costa Rica), Grand Cul-de-Sac Marin de la Guadeloupe (Guadeloupe), Jeanette Kawas National Park (Honduras) and Everglades National Park (United States). Unfortunately, where legislation exists, effective implementation is often lacking due to insufficient human resources. Plantation programmes in the region are generally undertaken as small reforestation or rehabilitation activities (mainly rehabilitation of shrimp farms), with the exception of Cuba, where a major plantation programme begun in 1980 continues.

Chapter 7
Oceania

VEGETATION AND SPECIES COMPOSITION

This region includes 23 countries and areas with mangroves and stretches from the Northern Mariana Islands (at Saipan Island, about 15° north latitude) to Western Port Bay, Australia (38°22′ south latitude). It includes Australia, Papua New Guinea, New Zealand and all the South Pacific islands where mangroves are known to exist.

Mangroves are commonly found in protected coastal bays, estuaries and shallow lagoons or on coral atolls. In northeastern Australia and in the Fly Delta in Papua New Guinea, they form dense and complex forests, which often extend far inland, while on some of the smaller islands such as Nauru and Niue, mangrove trees are found only as narrow belts along the coasts or in small isolated patches and stands. Some unusual mangrove communities are found on Vaitupu Island, in the coral archipelago of Tuvalu and on Christmas Island. In the first, trees grow to 6 m in height, even though the communities are almost cut off from the sea. On Christmas Island, stands of unusually tall trees of *Bruguiera gymnorrhiza* and *Bruguiera sexangula*, normally estuarine species, may be found at some 50 m above sea level at Hosnie's Spring (the world's smallest Ramsar site), and *Cynometra ramiflora* can be found at 220–300 m above sea level, on the east coast (a single stand, south of Ross Hill summit).

Mangroves in Oceania normally grow to 10–15 m, but may be taller in northeastern Australia (Queensland) and Papua New Guinea (30 m), in the Solomon Islands (25 m) and in Palau (20 m).

Mangrove biodiversity is very high in this region, and it is second only to that of Asia. As reported in Table 11, more than 50 true mangrove species grow in these countries. The greatest diversity is found in Australia and Papua New Guinea; both have more than 30 true mangrove species, including some endemic (i.e. *Avicennia integra*) and rare species (e.g. *Acanthus ebracteatus*) that are found only in these two countries. Another country with high mangrove biodiversity in the region is New Caledonia, which hosts more than 20 true mangrove species along its coasts.

One of the most notable features of mangrove vegetation in this region is the great discontinuity of the distribution of its flora. The reason for such discontinuity has long been a subject of debate (Duke, 1992; Ellison, 1995; Stoddart, 1992) and is as yet unknown.

Mangrove biodiversity in the smaller Pacific islands is significantly lower (for example only three species in Tuvalu and the Wallis and Futuna Islands, two in Nauru and one in New Zealand, Niue and Tokelau). The monospecific mangrove ecosystem found in Auckland harbour in New Zealand at 37°01′ south latitude (*Avicennia marina* var. *resinifera*) is particularly interesting due to its closeness to the southern limits of world mangrove distribution (38°22′ south latitude, Western Port Bay, Australia) and to its relatively simple structure.

MANGROVE RESOURCES: STATUS AND TRENDS 1980–2005

Oceania is the region with the smallest extent of mangroves worldwide (about 1 972 000 ha) (Table 3, page 10); 75 percent are concentrated in Australia (Table 12), which together with Papua New Guinea, the Solomon Islands, Fiji and New Zealand represent some 98 percent of the regional mangrove area (Figure 11). Mangrove forests and stands of a wide range of dimensions are found in this region, from the 2 ha of *Bruguiera gymnorrhiza* in Nauru (the smallest national mangrove community in the

TABLE 11
Mangrove species composition in countries of Oceania

Species	American Samoa	Australia	Christmas Island	Fiji	French Polynesia	Guam	Kiribati	Marshall Islands	Micronesia (Fed. States of)	Nauru	New Caledonia	New Zealand	Niue	Northern Mariana Islands	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Tokelau	Tuvalu	Vanuatu	Wallis and Futuna Isl.
Acanthus ebracteatus		√																					
Acanthus ilicifolius		√									√					√							
Acrostichum aureum	√				√	√			√[a]		√						√		√			√	√
Acrostichum speciosum		√							√														
Aegialitis annulata		√														√							
Aegiceras corniculatum		√														√		√					
Avicennia alba						√			√						√	√		√					
Avicennia eucalyptifolia																√							
Avicennia integra		√																					
Avicennia marina		√				√					√					√		√				√	
Avicennia marina var. *resinifera*												√											
Avicennia officinalis																√							
Avicennia rumphiana[b]		√														√							
Bruguiera cylindrica		√														√							
Bruguiera exaristata		√														√							
Bruguiera gymnorrhiza	√	√	√	√		√	√	√[c]	√	√	√			√	√	√	√	√	√			√	√
Bruguiera hainesii																√							
Bruguiera parviflora		√														√		√				√	
Bruguiera sexangula		√	√								√					√		√					
Camptostemon schultzii		√														√							
Ceriops australis		√														√							
Ceriops decandra		√														√							
Ceriops tagal		√							√		√				√	√		√				√	
Cynometra iripa		√							√		√					√							
Cynometra ramiflora			√								√					√							
Excoecaria agallocha		√		√		√			√		√		√		√	√		√	√			√	
Excoecaria indica																√							
Heritiera littoralis		√	√	√		√			√		√			√	√	√		√	√			√	
Kandelia candel																√							
Lumnitzera littorea		√		√		√	√		√		√				√	√		√	√		√	√	
Lumnitzera racemosa		√									√					√							
Lumnitzera x *rosea*		√									√												
Nypa fruticans		√				√			√						√	√		√					
Osbornia octodonta		√																√					
Pemphis acidula		√							√		√		√			√				√	√		
Rhizophora apiculata		√				√			√	√[a]	√				√	√		√				√	
Rhizophora x *lamarckii*		√							√		√							√					
Rhizophora mucronata		√				√	√		√						√	√		√				√	
Rhizophora samoensis	√			√							√					√	√		√				√

TABLE 11 (continued)
Mangrove species composition in countries of Oceania

Species	American Samoa	Australia	Christmas Island	Fiji	French Polynesia	Guam	Kiribati	Marshall Islands	Micronesia (Fed. States of)	Nauru	New Caledonia	New Zealand	Niue	Northern Mariana Islands	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Tokelau	Tuvalu	Vanuatu	Wallis and Futuna Isl.
Rhizophora x *selala*				√							√												
Rhizophora stylosa		√		√	√	√			√		√				√	√		√	√		√	√	
Scyphiphora hydrophyllacea		√							√		√				√			√					
Sonneratia alba		√					√		√		√				√	√		√				√	
Sonneratia caseolaris		√									√					√		√				√	
Sonneratia x *gulngai*		√																√				√	
Sonneratia ovata																√							
Sonneratia x *urama*		√																					
Xylocarpus granatum		√		√					√		√				√	√		√	√			√	
Xylocarpus mekongensis	√	√		√		√					√			√	√	√	√	√	√			√	
Total no. of species	**4**	**37**	**4**	**9**	**2**	**12**	**4**	**1**	**18**	**2**	**24**	**1**	**2**	**3**	**14**	**37**	**4**	**22**	**9**	**1**	**3**	**16**	**3**

[a] Uncertain.
[b] Also referred to as *Avicennia lanata*.
[c] *Bruguiera* sp. is reported for the country.

world) to the rich and complex ecosystem found in Australia with more than 1.4 million hectares. Although large, mangroves represent only 0.8 percent of Australia's total forest area and 0.1 percent of its total land area.

The remaining Pacific countries and areas, which often are small coral islands and archipelagos, have only very small areas of mangroves; the approximately 37 000 ha of mangroves covering the coasts of these small islands represent only 2 percent of the total regional extent and just 0.2 percent of world mangroves. Changes in these small areas do not significantly influence global figures. However, these forests are locally important and, in some cases, are the only forest habitat in the country. In Palau, to cite an example, mangroves grow on just 4 700 ha, but they represent 10 percent of the total land area.

According to the results of the present study, Oceania has lost about 209 000 ha of mangroves over the last 25 years (or about 9.5 percent of the area in 1980) (Figure 12). Even though significant, this loss is low in comparison with other regions. In absolute terms, the countries with the biggest area changes over the past two decades are Papua New Guinea, the Solomon Islands, Fiji and Australia, which are also among the five countries with the largest mangrove area in Oceania.

In Papua New Guinea, the area changes were caused primarily by human pressures for rural livelihoods, commercial activities and overexploitation of the resource (timber for housing and carvings). The extraction of fuelwood for domestic cooking and exportation contributed further to the decline of the mangrove forests of the Western Province. In the Solomon Islands, mangroves are used extensively for fuelwood and for timber for the construction of houses and boats. Overexploitation and conversion to other uses, including coastal development, have caused the majority of the losses over time. Their degradation continues, but efforts are being made to legally protect and regenerate the forests. In Fiji, the conversion to agriculture is the main cause of mangrove losses. Unfortunately, these ecosystems have minimal legal protection, and they are still threatened by increased sediment loads from upland logging, agriculture and local pollution.

TABLE 12
Status and trends in mangrove area – Oceania (1980–2005)

Country/ area	Most recent reliable estimate		1980	1990	Annual change 1980–1990		2000	Annual change 1990–2000		2005	Annual change 2000–2005	
	ha	Ref. year	ha	ha	ha	%	ha	ha	%	ha	ha	%
American Samoa	52	2003	75	73	n.s.	–0.3	57	–2	–2.4	49	–2	–3.0
Australia	1 451 411	2005	1 458 000	1 455 000	–300	n.s.	1 453 000	–200	n.s.	1 451 000	–400	n.s.
Christmas Island	n.a.	n.a.										
Fiji	42 464	1991	47 000	43 000	–400	–0.9	38 700	–430	–1.0	36 600	–420	–1.1
French Polynesia	n.a.	n.a.	n.a.	n.a.			n.a.			n.a.		
Guam	70	1993	88	74	–1	–1.7	60	–1	–2.1	55	–1	–1.7
Kiribati	258	1995	260	260	0	0	250	–1	–0.4	250	0	0
Marshall Islands	n.a.	n.a.										
Micronesia (Fed. States of)	8 564	1983	8 500	8 500	0	0	8 500	0	0	8 500	0	0
Nauru	2	1991	2	2	0	0	2	0	0	2	0	0
New Caledonia	17 140	2003	20 800	20 000	–80	–0.4	18 000	–200	–1.1	16 600	–280	–1.6
New Zealand	26 032	2001	28 000	26 000	–200	–0.7	26 000	0	0	26 000	0	0
Niue	3 000	1981	3 000	3 000	0	0	3 000	0	0	3 000	0	0
Northern Mariana Islands	7	1976	7	7	0	0	7	–0.1	–0.7	6	n.s.	–0.3
Palau	4 708	1985	4 700	4 700	0	0	4 700	0	0	4 700	0	0
Papua New Guinea	410 000	2000	545 000	472 000	–7 300	–1.4	410 000	–6 200	–1.4	380 000	–6 000	–1.5
Samoa	370	1999	1 000	670	–33	–3.9	370	–30	–5.8	350	–4	–1.1
Solomon Islands	50 572	1993	60 400	53 000	–740	–1.3	45 300	–770	–1.6	41 500	–760	–1.7
Tokelau	n.a.	n.a.	n.a.	n.a.			n.a.			n.a.		
Tonga	1 305	1997	1 500	1 400	–10	–0.7	1 300	–10	–0.7	1 300	0	0
Tuvalu	40	1993	50	50	0	0	40	–1	–2.2	40	0	0
Vanuatu	2 519	1993	3 000	2 700	–30	–1.0	2 500	–20	–0.8	2 500	0	0
Wallis and Futuna Islands	25	2005	25	25	0	0	25	0	0	25	0	0
Oceania	**2 018 539**	**2003**	**2 181 407**	**2 090 461**	**–9 094.60**	**–0.42**	**2 011 811**	**–7 865**	**–0.38**	**1 972 477**	**–7 867**	**–0.39**

Note: n.a. = not available; n.s. = not significant.

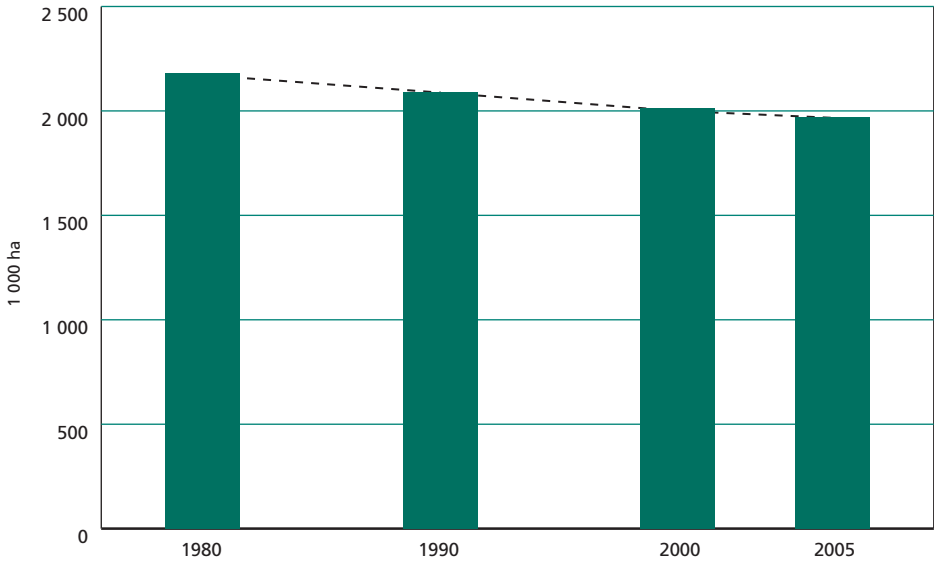
In relative terms, Pacific islands such as Samoa, Guam and American Samoa have experienced the largest losses of mangroves. Most of the Samoan mangroves have been extensively exploited and much of the forest that remains is degraded. In Guam, on the other hand, dredging of wetlands has been the main cause of mangrove loss, while in American Samoa, development pressures (filling, seawall construction, pollution, and dumping of waste and oil) have significantly reduced the mangrove area. Protective laws exist,, but they are not well enforced. Small reforestation and protection initiatives are slowly beginning to rehabilitate the mangrove forests in Western Samoa (e.g. a small patch of mangroves was reforested in 2003 in Nu'uuli), but much remains to be done.

MAIN USES AND THREATS

On several of the smaller Pacific islands, mangroves represent the only forest type and are a source of wood for local communities. They have traditionally been used for the production of fuelwood and as timber, posts and poles for the construction of houses

FIGURE 11
Five countries with the largest mangrove area – Oceania (2005)

FIGURE 12
Mangrove area changes over time – Oceania (1980–2005)



and boats, which in some cases has resulted in overexploitation of the resource. In Australia, on the other hand, where there is an abundant supply of hardwood timber from other forest types, the use of mangrove wood has been very limited and several mangrove forests remain well conserved.

As in other regions, mangrove ecosystems are traditionally used for the collection of fish, shellfish and crabs. Limited areas of mangrove forest have been cleared to convert the land to shrimp farms, but this industry has not expanded as much in this region as in other parts of the world. In some Pacific countries (e.g. Fiji, the Northern Mariana Islands and Vanuatu), mangrove areas have been converted to agriculture (especially sugar production and rice paddies). Local communities on these islands also harvest and collect non-wood products from these forests, such as food, medicine and tannin. The leaves of the nipa palm are traditionally used for thatching and weaving (as in Asia) and the sap is used for the production of alcohol.

One of the primary causes of mangrove degradation and loss in this region has been the development of tourism infrastructure. In most of these countries and territories, tourism is a main contributor to the national economy, but the construction of resorts and other tourism infrastructure has often been undertaken at the expense of coastal ecosystems, including mangroves. Mangrove areas have also been cleared to facilitate urban development. Currently, several mangrove areas and other coastal ecosystems are threatened by industrial pollution, as in New Caledonia, or by domestic and solid wastes and local pollution, as in Fiji, Kiribati and Tuvalu (S.Vedel, unpublished, 2005; Maharaj, 2002; USDA Forest Service, 1998; United Nations, 1998).

MANGROVE CONSERVATION AND MANAGEMENT

Countries in the region increasingly recognize the value of healthy mangroves and are protecting these coastal ecosystems by establishing or enlarging natural reserves and parks. Some examples are found in the Northern Mariana Islands, where most mangroves are included in the American Memorial Park; in the Solomon Islands, where, even though still threatened, mangroves are protected from commercial logging and export under the Forest Resources and Timber Utilization Act; or in Vanuatu, where commercial logging of mangroves is completely banned.

Over the past decades, New Zealand has occasionally removed mangroves for coastal development and agriculture, but increased awareness of the services and benefits provided by these coastal ecosystems led to the preparation of new legislation in the early 1990s that significantly limited the clearing of mangroves. Owing to this legislation and the change of management that came into force in those years, area losses in the country decreased drastically, allowing a slight natural expansion of mangroves into new areas through the colonization of sedimented land. A similar process is occurring in eastern Australia, where in most states the clearing of natural vegetation is prevented or controlled by specific laws. Small-scale programmes of mangrove reforestation and afforestation have been recorded in New Caledonia and American Samoa.

Chapter 8
South America

VEGETATION AND SPECIES COMPOSITION

Mangrove forests in South America are found on the Atlantic and Pacific coasts and in the bays and estuaries of eight countries. They are distributed from the Praia do Sonho in the south (State of Santa Catarina, Brazil) to the city of Sechura, along the Piura River (Peru), where only monospecific forests are found (*Avicennia germinans*).

A wide range of mangrove tree heights may be found in the different countries of this region and even within the same country. While their canopy cover rarely exceeds 20 m in height, tall trees of 45 to 50 m may be found, for example in the 'Manglares Cayapas-Mataje' Ecologic Reserve (Ramsar site) or in the states of Amapá, Pará, and Maranhão (Brazil), where there are specimens of *Avicennia* spp. with a diameter of about 1 m and trees of *Rhizophora harrisonii* reaching 40–45 m. In these areas, mangroves extend up to 40 km inland and they remain relatively unthreatened due to the inaccessibility and low human population density. Well-developed mangrove communities are also found in the delta of the Amazon River, where trees can reach 40 m in height, sustained by high rainfall and by the river system itself. Due to the extremely high inputs of freshwater here, mangroves have to compete with local freshwater hardwoods, lianas and palms, which restricts mangrove distribution in the area. The Pacific coast of Colombia and the Orinoco delta of the Bolivarian Republic of Venezuela have significant mangrove forests as well, with trees up to 30 m in height, while 20–25-m mangrove trees have been reported in Guyana.

As is the case in North and Central America, mangrove forest structure and species composition in South America differ from one coast to the other. Colombia is the only country with both Caribbean and Pacific coasts. More than 70 percent of its mangroves are found on the Pacific coast, where they form well-structured, tall forests. The lower rainfall and smaller tidal fluctuations of the Caribbean coast limit forest development, and only small, narrow fringes of mangroves are found (sometimes in the form of dwarf trees as in the Guajira department). Notwithstanding these limitations, some well-developed mangrove forests also grow along this coast, for example in the Magdalena river estuary.

The mangrove tree species diversity of this region is low – only ten native species (Table 13) – the lowest worldwide. Three species (*Avicennia germinans, Laguncularia racemosa* and *Rhizophora mangle*) are very common and are found in all eight countries; others, such as *Avicennia bicolor* and *Pelliciera rhizophorae,* are found with less frequency or their presence is uncertain.

MANGROVE RESOURCES: STATUS AND TRENDS 1980–2005

Mangroves in South America currently cover slightly less than 2 million hectares, down from some 2.2 million hectares in 1980.

About half the mangrove area of the region is found in Brazil – which also has the third largest mangrove area in the world (Table 14 and Figure 3, page 12). More than 90 percent is found in five countries: Brazil, Colombia, the Bolivarian Republic of Venezuela, Ecuador and Suriname (Figure 13). Guyana, French Guiana and Peru share the remaining 140 000 hectares. The relatively small mangrove area in these countries might be explained by the relatively small land area (Guyana) or by the narrow and in some zones arid or rugged coasts of Peru and French Guiana, which are not well suited to the development of mangroves.

TABLE 13
Mangrove species composition in South American countries

Species	Brazil	Colombia	Ecuador	French Guiana	Guyana	Peru	Suriname	Venezuela (Bolivarian Rep. of)
Acrostichum aureum		√	√				√	
Avicennia bicolor		?[a]						
Avicennia germinans	√	√	√	√	√	√	√	√
Avicennia schaueriana	√				√			√
Conocarpus erectus	√	√[b]	√		√	√		√
Laguncularia racemosa	√	√	√	√	√	√	√	√
Pelliciera rhizophorae		√	√					
Rhizophora harrisonii	√	√[c]	√			√		√
Rhizophora mangle	√	√	√	√	√	√	√	√
Rhizophora racemosa	√	?[a]		√				√
Total no. of species	**7**	**9**	**7**	**4**	**5**	**5**	**4**	**7**

[a] Uncertain.
[b] Found on both coasts, but rare on the Pacific coast.
[c] Found only on the Pacific coast.

TABLE 14
Status and trends in mangrove area – South America (1980–2005)

Country/ area	Most recent reliable estimate		1980	1990	Annual change 1980–1990		2000	Annual change 1990–2000		2005	Annual change 2000–2005	
	ha	Ref. year	ha	ha	ha	%	ha	ha	%	ha	ha	%
Brazil	1 012 376	1991	1 050 000	1 015 000	–3 500	–0.3	1 000 000	–1 500	–0.1	1 000 000	0	0
Colombia	371 250	1997	440 000	393 000	–4 700	–1.1	360 300	–3 270	–0.9	350 000	–2 060	–0.6
Ecuador	149 556	1999	203 000	163 000	–4 000	–2.2	150 200	–1 280	–0.8	150 500	60	n.s.
French Guiana	55 000	1980	55 000	55 000	0	0	55 000	0	0	55 000	0	0
Guyana	80 432	1992	91 000	82 200	–880	–1	80 000	–220	–0.3	80 000	0	0
Peru	4 550	1995	8 300	5 800	–250	–3.5	4 500	–130	–2.5	4 500	0	0
Suriname	114 600	1998	115 000	114 800	–20	n.s.	114 600	–20	n.s.	114 400	–40	n.s.
Venezuela (Bolivarian Rep. of)	250 000	1986	260 000	244 500	–1 550	–0.6	231 000	–1 350	–0.6	223 500	–1 500	–0.7
South America	**2 037 764**	**1992**	**2 222 300**	**2 073 300**	**–14 900**	**–0.69**	**1 995 600**	**–7 770**	**–0.38**	**1 977 900**	**–3 540**	**–0.18**

Note: n.a. = not available; n.s. = not significant.

During the 1980s and 1990s, mangrove lands were often considered unproductive and unhealthy. This attitude and the resultant activities caused a loss of some 250 000 ha of mangroves in the region (11 percent of the 1980 extent) (Figure 14). This loss is low in comparison with other regions, but can be significant at the national and local levels, where rural populations often depend on mangroves for subsistence and for commercial fishing.

In absolute terms, the countries that experienced the highest losses of mangroves were Colombia, Ecuador, Brazil and the Bolivarian Republic of Venezuela, all of them with more than 30 000 ha of mangroves lost since the 1980s. In Colombia the extent of mangroves has continued to decline over the past 25 years, even though the annual change rate has decreased from –1.12 percent (1980–1990), to –0.86 percent (1990–2000) and finally to –0.58 percent in the last five years. Extensive conversion for shrimp ponds, development of urban, industrial and tourist infrastructures and reclamation of land for agricultural crops and pasture led to the loss of 90 000 ha since the 1980s. Awareness of

FIGURE 13
Five countries with the largest mangrove area – South America (2005)

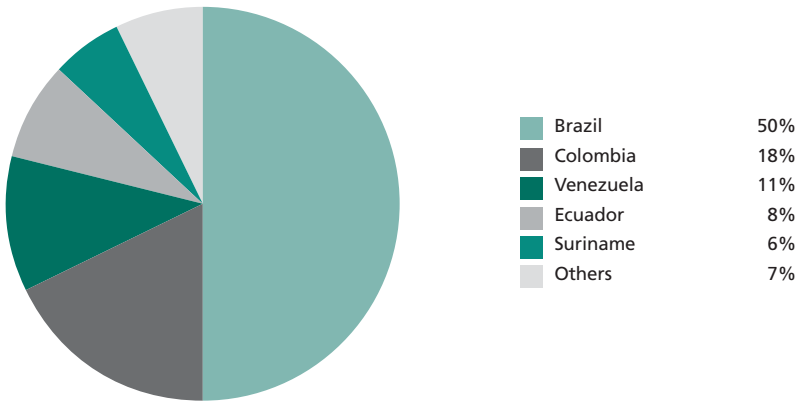
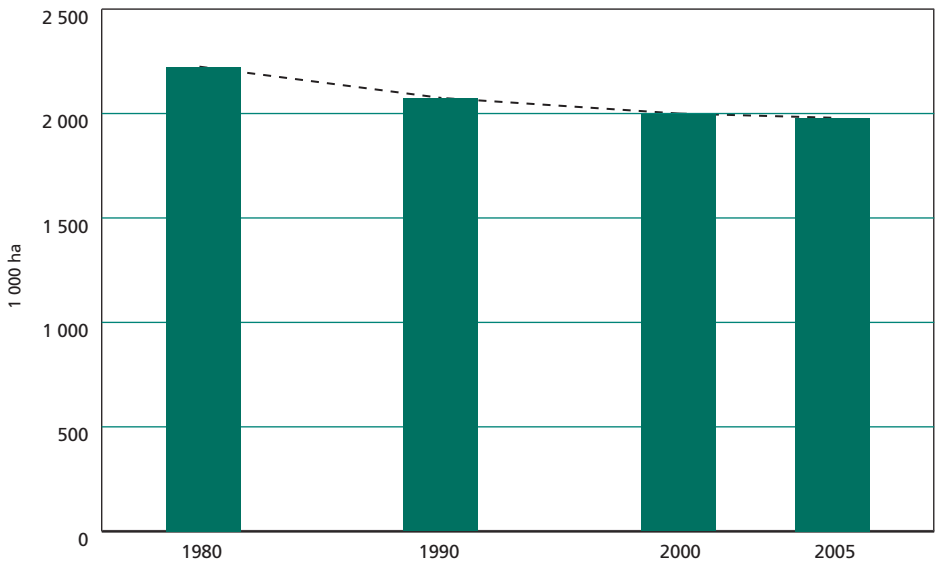


FIGURE 14
Mangrove area changes over time – South America (1980–2005)



the importance of this coastal ecosystem is now slowly increasing and some efforts in reforestation and/or afforestation have been undertaken (2000) as a joint initiative by the Ministry of the Environment (Ministerio del Ambiente), the Corporación Nacional de Investigación y Fomento Forestal (CONIF), ITTO and local communities.

One success story comes from Ecuador, where the significant losses of the 1980s and 1990s (some 40 000 ha) are slowly being recovered and the mangrove area now seems to be stable. The main cause of loss of mangroves was the unsustainable development of shrimp ponds, which started in 1966 as a small-scale activity. However, high international demand converted shrimp into a major trade item, and Ecuador rapidly became one of the largest producers in South America. The industry brought significant gains to the country and to local populations, becoming one of the economic activities with the most growth nationally and in the region. The outbreak in Ecuador of the white-spot syndrome virus (WSSV) had a tremendous impact on the shrimp-

farming industry. This impact, together with the activities of several environmental organizations, the consequent abandoning of the ponds, the ban on mangrove cutting implemented in 1994 and the increase in field controls, favoured the natural recolonization of mangroves in several places. The combination of these factors led to a slight increase in the extent of mangroves from 2000 to 2005.

Brazil lost at least 50 000 ha of mangroves over the last 25 years, mainly along the southern coast. The country still possesses significant and relatively pristine mangrove forests, because most mangrove areas are located in the less urbanized northern states. No recent quantitative national data are available (other than the 1991 figures reported in Table 14). However, the relatively low population pressure on the northern states and government efforts to protect and rehabilitate damaged forests seem to have contributed to a major reduction in the loss of mangrove area, which is estimated at zero in the period 2000–2005. New and updated inventories are needed to provide more detailed estimates for this country. It is hoped that a recently approved Global Environment Facility (GEF) project (Conservation and Sustainable Use of the Biodiversity of the Globally Important Brazilian Mangrove) will contribute to filling current information gaps.

Among the most significant causes of past losses and conversions are the intensive use for timber production, urban development (southeastern states) and to a lesser extent for fuelwood. Mariculture (mainly shrimp farming) began in Brazil in the 1970s and it is now widely practised – primarily along the coast of the northeastern states (e.g. Ceará, Rio Grande do Norte) – and still represents a significant threat to mangroves. The impact of this activity is a national concern, mostly because of the consequent eutrophication of the waters caused by the high emission of nitrogen and phosphorus and the widespread illegal cutting of mangroves. In 2003 shrimp farms covered approximately 13 000 ha, many of these adjacent to mangrove forests, which has generally resulted in eutrophication of mangrove creeks and tidal channels.

Intensive use of mangrove forests as a source of fuelwood, development of urban and tourist infrastructures and conversion of land use to agriculture appear to be the main causes of mangrove area changes in the Bolivarian Republic of Venezuela, where more than 35 000 ha disappeared in the past 25 years. Some additional losses and degradation have been caused by oil spills. In this country, as well, the government is now making efforts to protect these coastal ecosystems.

In relative terms, the country that experienced the largest loss was Peru (annual change rate 1980–2005: –2.42 percent), followed by Ecuador (–1.19 percent), Colombia (–0.91 percent) and the Bolivarian Republic of Venezuela (–0.60 percent). Mangroves in Peru have traditionally been used for the production of fuelwood, charcoal and poles. However, the main cause of their loss is uncontrolled clearing for conversion of the land into shrimp ponds. This activity began in the 1970s and soon became a major source of employment for many farmers. For example, the industry led to the expansion of the city of Tumbes, which has nearly doubled its population since the 1960s. The logging of mangroves is now banned and this, together with the increasing protection and control of the major mangrove forest in the country (Santuario Nacional Los Manglares de Tumbes), may have led to the reduction of the annual rate of loss, which appears to be close to zero in the last five years (2000–2005).

French Guiana is the only country in the region that did not experience major changes in mangrove area over the past two decades. In this country, other forest types are used as the principal source of timber/fuelwood, and no serious threats seem to pressure the mangroves. Unfortunately, however, the area estimates for this country had to be based on qualitative information, because no reliable data were available since 1980 (Table 14). New inventories are needed in order to have a clearer picture of the current extent of mangroves.

In Guyana, as well, updated inventories would contribute greatly to a better estimate of the extent of the mangroves.

MAIN USES AND THREATS

Mangrove forests in South America have traditionally been used for a wide range of purposes, and the local population still often rely on them for their livelihood. The collection of wood forest products is a common practice. Timber and fuelwood are harvested from mangroves in Brazil, Colombia, Ecuador, Guyana, Peru and the Bolivarian Republic of Venezuela. Production of charcoal from these forests seems to be less widespread, but it is a traditional practice in Colombia, Ecuador, Guyana and Peru. Extraction of tannin from the bark of mangrove trees (especially of *Rhizophora mangle*) was previously a common activity in Brazil, Colombia, Ecuador and Guyana, and contributed substantially to supplying national industries.

Rural communities often rely on mangroves as a source of food and additional income through the collection of non-wood forest products. Molluscs, crabs and other crustaceans are collected for local use or for national consumption. In Ecuador, for example, 2.0–2.5 million molluscs are collected every month from mangrove forests (Spalding *et al.*, 1997). In Guyana, *Avicennia germinans* seeds are used as food. Mangrove forests also indirectly influence the local economy by aiding commercial and small-scale fishing activities, which in the Bolivarian Republic of Venezuela, for example, have an important role in the national economy.

Mangrove forests have been converted to other land uses, such as the production of salt (Ecuador) or reclaimed for agriculture (especially in Colombia, Ecuador and Guyana) or for urban and tourism development (e.g. in Colombia and the Bolivarian Republic of Venezuela). In addition, as was described in the previous section, the conversion of mangrove lands for shrimp ponds was a major cause of mangrove destruction in past years, and even though this activity has been reduced, it still represents a significant threat.

Awareness of the importance of these coastal ecosystems is growing, but limited understanding of their services and benefits and lack of harmonization and implementation of existing laws still represent threats to mangroves. These forests continue to be under serious threat also from increasing urban and industrial pollution (e.g. Peru), the flow of pesticides to coastal zones (e.g. Suriname) and oil spills (particularly in the Bolivarian Republic of Venezuela). The planning and construction of dams or changes in river flows upstream are also current threats. These decrease the freshwater input, consequently increasing salinity and reducing nutrients and sediments transported to the coast.

Mangroves have a significant role in erosion and accretion along the coastline. An interesting case comes from French Guiana. The entire coast of this country is affected by the load dispersal system associated with the mouth of the Amazon River (located some 500 km east of the country), from which some 1 billion tonnes of sediment are poured into the ocean every year. It is estimated that 10 percent reaches the coasts as suspended load (Rudant, 1994). The mangroves assist in trapping these sediments.

MANGROVE CONSERVATION AND MANAGEMENT

Awareness of the importance of these forests is slowly but steadily increasing, and mangroves are under some form of protection in most countries of South America. However, illegal cutting and use is unfortunately continuing. Legal protection of mangroves has a long history in Brazil, where the earliest record dates from 1760. The King of Portugal, concerned about the loss of potential sources of tannin, issued an edict to restrict the cutting of mangroves for fuelwood unless their bark was also used. More recently, the government has published laws to conserve mangroves and to establish 12 new protected areas. In addition, projects for the conservation and sustainable use of mangroves in protected areas are being prepared, which could help reduce pressure on these forests.

Afforestation and reforestation activities have been undertaken (e.g. in Colombia and Guyana). All South American countries with the exception of Guyana have at

least one Ramsar mangrove site, indicating added political will to protect these habitats and their environmental richness. However, more efforts could be undertaken at the national and regional levels to implement appropriate strategies and effectively protect these ecosystems.

In Ecuador, after extensive mangrove clearing during the 1970s, the government declared mangroves protected forests in 1986 and prohibited cutting of mangrove trees in 1994. Forest protection policies and legislation exist in Guyana, as well, although not dealing directly with mangroves. In Suriname mangroves are protected together with other swamp forests in multiple-use management areas, and in Peru, where mangrove clearing is now prohibited, most mangroves have been protected since 1980 in the Santuario Nacional Los Manglares de Tumbes, which was declared a Ramsar site in 1997.

Chapter 9
Discussion

As with all analyses, the reliability of the results depends on the quality of the input. This chapter provides information on overall data availability and quality, describing specific issues in the determination of the most recent reliable estimates and of trends. Lack of comprehensive information and changes in methodologies and, to a lesser extent, definitions from one assessment to another represented the most serious difficulties faced in comparing national estimates and analysing trends. Political boundaries of a few countries have changed over the years and/or additional mangrove areas have been discovered only recently, making trend analyses very challenging.

DEFINITIONS USED

In the present study, mangrove areas were broadly defined as areas containing one or more true mangrove species (based on Tomlinson, 1986, and Saenger, Hegerl and Davie, 1983[2]). No attempt was made to reclassify areas defined as mangrove forests in the original sources. All definitions used in the original sources have been entered into the global database. Where possible, waterways and other vegetation types existing within the larger mangrove forest and areas of freshwater swamp were subtracted from the total area. Mangroves are a relatively distinct and, in most cases, easily demarcated forest type, and consequently the problem of different definitions over time is deemed to be less significant than the problems caused by the use over time of varying methodologies and sampling intensities and potential interpretation errors.

OVERALL DATA AVAILABILITY

Quantitative or qualitative information on the current status and extent of mangroves has been found for all 124 countries and areas in which these coastal ecosystems are known to exist. More than 2 900 national and subnational data sets were collected, with the earliest estimates dating from 1888. Of the countries included in this assessment, 90 were reporting through national experts and focal points during the initial phases of the study, providing FAO with essential information for a reliable evaluation.

The database of mangrove area estimates currently includes 2 969 data sets for the countries and areas included in the study. The total number of references is 630; of these, 43 provide global or regional information on mangrove areas, while the remaining 587 are country specific. A total of 1 153 data sets provide national estimates (including those with breakdowns to subnational units), while 1 816 data sets provide only subnational figures, covering provinces or key mangrove areas within a given country. Some of the data sets are secondary sources that repeat past estimates. The total number of different national estimates is therefore 899 – an average of seven different estimates over time per country or area. The information availability per region (i.e. the number of national estimates and their reliability) is illustrated in Figure 15.

Despite concerted efforts, no quantitative data were identified on the extent of mangroves in seven countries/territories (Table 15); only qualitative information was obtained indicating the presence of mangroves on their coasts. Even though the total mangrove extent in these countries is assumed to be low and does not greatly influence the world total, an assessment should be undertaken soon in order to fill in gaps in current knowledge. This information will also aid in the preparation of sustainable use plans and the management of these resources.

[2] See 'Definition of true mangrove species', page 8.

For six other countries/territories (corresponding to 0.1 percent of the 2005 world mangrove area), only a single estimate was identified (Table 15). Efforts should be made to increase the knowledge of mangrove resources in these 13 countries and territories.

Conversely, ten or more national estimates over time were identified for 37 countries, which represent more than 80 percent of the current extent of world mangrove area. Among these, some have more than 15 different estimates over time (Table 16).

DATA QUALITY

The methodology used in the studies and assessments reviewed to generate national mangrove area estimates (Table 17) provides an indication of the quality of data collected during the present study.

FIGURE 15
Information availability and reliability – national mangrove area estimates by region

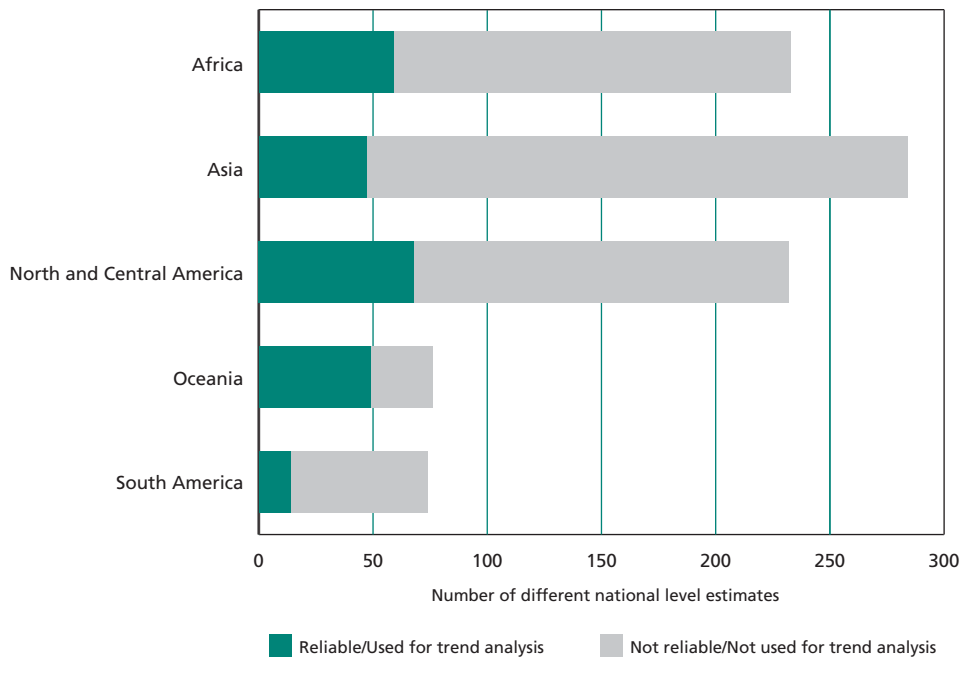


TABLE 15
Countries and areas with poor or no national data

Country/area	No. of estimates
Djibouti	1
Micronesia (Fed. States of)	1
Niue	1
Northern Mariana Islands	1
Seychelles	1
Wallis and Futuna Islands	1
British Indian Ocean Territory	no data
Christmas Island	no data
French Polynesia	no data
Maldives	no data
Marshall Islands	no data
Sao Tome and Principe	no data
Tokelau	no data

TABLE 16
Countries with good national data

Country	No. of estimates
Philippines	49
Thailand	34
Indonesia	26
India	24
Ecuador	21
Bangladesh	17
Viet Nam	16
Malaysia	16
Mexico	16
Costa Rica	16
Guinea	16
Madagascar	16

TABLE 17
Data quality

Region	All national estimates									Most recent reliable estimate							
	Total no.	Ground survey		Remote sensing/ mapping		Expert estimate		Not known		Ground survey		Remote sensing/ mapping		Expert estimate		Not known	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Africa	233	5	2	99	42	31	13	98	42	2	6	25	78	4	13	1	3
Asia	284	6	8	75	144	52	34	151	53	2	8	11	46	4	17	7	29
North and Central America	232	15	6	82	35	55	24	80	34	10	29	13	38	8	24	3	9
Oceania	76	3	4	29	38	12	16	32	42	2	11	11	58	3	16	3	16
South America	74	0	0	31	42	16	22	27	36	0	0	6	75	0	0	2	25
World	**899**	**29**	**3**	**316**	**35**	**166**	**18**	**388**	**43**	**16**	**14**	**66**	**56**	**19**	**16**	**16**	**14**

Note: The percentages given for the various methodologies refer to the number of national estimates using the related methods and not to mangrove area coverage.

About 38 percent of all national estimates were based on ground surveys (3 percent) or remote-sensing imagery interpretation and/or mapping (35 percent). Ground surveys were carried out in all regions, but only to a very limited extent and at a lower percentage than with other methodologies, probably due to the costs involved in conducting large-scale inventories with this methodology and the additional logistic difficulties that have to be faced when undertaking such inventories in these ecosystems. No such inventories were reported for South America. Tidal changes and the complexities of undertaking a classic field survey in mangrove forests make their assessment difficult and time consuming. Consequently, more institutes and governments are making use of remote sensing imageries coupled with Geographic Information System (GIS) technology for their inventories. The new digital technologies used in India, for example, improved the minimum mapping area to one hectare, allowing the preparation of accurate estimates.

Unfortunately, the methodology used in assessments was often not reported (43 percent); where this is due to reliance on secondary sources, further attempts will be made to obtain copies of the original inventories.

In the framework of this study, only the most reliable estimates were taken into account for the trend analysis. Despite efforts to find as many reliable estimates as possible, for 40 countries and areas (mainly from Africa and the Caribbean) only one estimate was considered reliable. Even though more estimates were available, discrepancies among them (e.g. differences in methodologies, exclusion of some mangrove sites in the country, low resolution of the mapping scale, etc.) did not allow a proper comparison and analysis of area changes. For a few of these countries and areas (e.g. Anguilla, Aruba, French Guiana and Qatar), qualitative information indicated no major changes over the last 20 years, while for others the estimates for 1980, 1990, 2000 or 2005 were produced by applying the annual change rates for forests calculated for the global forest resources assessments (FAO, 1995b, 2001a, 2006). The total area of mangroves estimated to be currently growing along the coasts of these 40 countries and areas is just 2.5 percent of the global mangrove area and thus does not greatly influence the world total. However, this study recommends focusing future attention on these countries in order to increase the availability of reliable data.

On the other hand, the analysis of changes in area for 39 countries/territories (61.6 percent of worldwide mangrove area) was based on three or more reliable data sets over time, and for eight of these on more than five data sets (Table 18).

TABLE 18
Countries with five or more reliable estimates used for the trend analysis

Country	No. of reliable estimates	Time range analysed
Viet Nam	7	1943–2000
Cuba	6	1972–2003
Malaysia	6	1995–2005
Peru	6	1976–1995
Ecuador	5	1984–1999
El Salvador	5	1981–2004
Pakistan	5	1980–2001
Philippines	5	1918–2003

MOST RECENT RELIABLE ESTIMATE

The majority of estimates selected as the most recent reliable national estimate are based on detailed ground surveys (14 percent) and/or accurate remote sensing imagery interpretation (56 percent) (Table 17). The weighted average year for the world total (15 704 958 ha) is 2000, which makes this study the most up-to-date and comprehensive assessment ever undertaken on this subject at the global level.

Recent reliable estimates by country dating from 2000 or later were identified for 45 countries (or 64 percent of the total current mangrove area), while such estimates dating from 1995 to 2000 were found for an additional 30 countries. These two sets of countries together account for 87 percent of the global mangrove area.

For 25 countries and areas, the most recent reliable estimate dated from 1990 to 1995; 36 percent of these were Caribbean islands, often dating back to 1991 (Bacon, 1993). For 17 countries and areas the most up-to-date estimate dated from before 1990. Half of these are arid-zone countries or small island developing states (SIDS). Mangroves here, with a few exceptions (e.g. the Bolivarian Republic of Venezuela, French Guiana and Kenya), cover a relatively small area totalling less than 3 percent of the world extent.

Estimates for Indonesia, Australia and Mexico (among the five countries with the largest mangrove cover worldwide) covered a wide range of time, with a weighted average reference year of 2001. Brazil and Nigeria (the other two countries among the top five) have most recent information dating only from 1991 and 1995 respectively.

TRENDS OVER TIME AND IMPEDIMENTS TO THE ASSESSMENT

The abundant feedback received from the countries, coupled with an intensive literature search, provided estimates covering more than 100 years, with the earliest assessments dating from 1888 (Australia) and 1918 (Philippines), and the most recent ones dating from 2005 (Australia, Japan, Malaysia and the Wallis and Futuna Islands).

At the global level, trend analyses were hampered by three main difficulties: lack of comprehensive data over time, differences in definitions used and differences in methodologies over time, which represented the most serious problem. When selecting the estimates to be used for trend analysis, preference was given to estimates based on field inventories and/or remote sensing. However, in some instances it was not possible to exclude estimates for which the methodology was unknown. The apparently large mangrove loss in Indonesia, for example, may in part be due to the use of different methodologies over time. Some over- or underestimation of area changes may also be caused by the different scales and sampling intensities. In some cases, the 'no significant area changes over time' reported by some countries may be only apparent – the result of a lack of reliable estimates, not allowing proper trend analysis and imposing the use of only qualitative information to assess the current extent of mangroves.

A list of national estimates by country – including full references and information on methodology, reliability and use for trend analysis – and the results of the individual

trend analyses for each country and area are provided in the five regional working papers complementary to the main study listed in Annex 2.

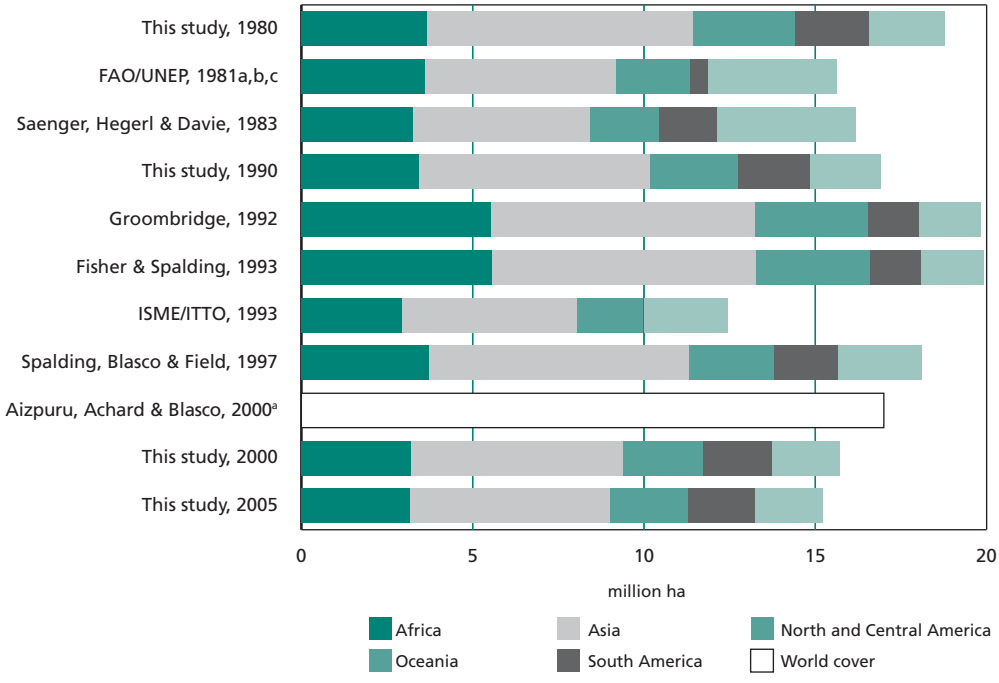
COMPARISON WITH PREVIOUS STUDIES

Figure 16 compares the results of the present study with previous global estimates. Keeping the cited caveats in mind, the results indicate that the 1980s estimates of total mangrove area were too low (primarily due to the limited number of countries included), whereas those made in the 1990s and 2000 were too high, with the exception of ISME/ITTO in 1993, which included fewer countries.

TABLE 19
Countries and areas with most recent reliable estimate predating 1990

Country/area	Reference year
Benin	1989
Mayotte	1989
Haiti	1988
Turks and Caicos Islands	1988
Aruba	1986
Venezuela (Bolivarian Rep. of)	1986
Djibouti	1985
Palau	1985
Saudi Arabia	1985
Micronesia (Fed. States of)	1983
Kenya	1982
Niue	1981
French Guiana	1980
Netherlands Antilles	1980
Northern Mariana Islands	1976
Somalia	1975
Seychelles	1960

FIGURE 16
Comparison with previous studies



[a] No breakdown by region was reported.

The new estimates provided by the present study for 1980, 1990 and 2000, as well as those presented as the most recent reliable estimates, are presumed to be the best available. The extrapolation to 2005 is, by definition, less reliable – particularly where few or no recent assessment results were available. This estimate is thus only indicative and is likely to change as and when results from ongoing and future assessments become available.

Chapter 10
Conclusions

Mangroves fulfil many necessary functions from the productive, protective and social points of view. Yet increased population pressures in coastal areas and lack of awareness have led to large-scale conversion of mangrove areas to other uses. Numerous case studies and anecdotal evidence exist describing mangrove losses over time. However, access to comprehensive information on the status and trends of mangrove areas at the global level has been limited.

Analysis of the most recent reliable estimate identified for each country and area shows that the area of mangroves varies from a few hectares (e.g. Nauru, with 2 ha) to more than 1 or 2 million hectares in individual countries and that five countries (Indonesia, Australia, Brazil, Nigeria and Mexico) account for about 47 percent of the global area of these ecosystems. More than 60 percent of the total mangrove area is found in just ten countries. By region, the largest areas of mangroves are found in Asia and Africa, followed by North and Central America.

The study illustrates the problems that varying methodologies over time – and lack of recent, reliable information for a few countries – create in generating reliable trends. The estimate for 2005 is thus indicative and is likely to change when results from ongoing and future assessments become available.

Nevertheless, the trend analysis indicates that the current mangrove area worldwide has fallen to about 15.2 million hectares, down from 18.8 million hectares in 1980. The world has thus lost some 3.6 million hectares of mangroves over the last 25 years, or 20 percent of the extent found in 1980.

The study also indicates that the loss of mangroves continues at alarming rates, but that the rate of net loss is showing signs of slowing down – in line with the trend in forests (FAO, 2006a). From about 185 000 ha lost every year in the 1980s, the net loss dropped to some 118 500 ha per year in the 1990s and to 102 000 ha per year (or a loss of 0.66 percent annually) during the 2000–2005 period, reflecting an increased awareness of the value of mangrove ecosystems. Most countries have now banned the conversion of mangrove areas for aquaculture purposes and require environmental impact assessments prior to large-scale conversion of these areas for other uses. This has led to new legislation, better protection and management and, in some countries, to an expansion of mangrove areas through active planting or natural regeneration.

Even though mangroves have been often used for the collection of wood forest products and as a source of subsistence for local populations, wood removal is rarely the main cause of loss. Human pressure on coastal ecosystems and thus competition for land for aquaculture, agriculture, infrastructure and tourism are often intense and are among the major causes of the reported decrease in these forest areas over time. More specifically, the relatively large losses of mangrove areas in Asia, the Caribbean and Latin America during the 1980s were caused primarily by large-scale conversion of these areas for aquaculture and tourism infrastructure. On a positive note, integrated coastal area management has been identified as a possible solution to competing land uses in several countries.

In addition to providing access to all primary data and thus facilitating analysis of these by others, the database prepared during this study also indicates where information is lacking and where efforts should be directed in order to obtain more recent and reliable estimates.

FIGURE 17
Future of mangroves – a human choice

M. WILKIE

Mangrove stand killed by pollutants

S. FORTUNA

Healthy and protected forest

M. WILKIE

Mangrove area converted to other land use

M. WILKIE

Multiple use of the ecosystem

FAO/FO-6382/M. KASHIO

Degraded mangroves

M. WILKIE

Mangrove rehabilitation

Better information is needed on both the extent and the condition of mangroves as an aid to policy- and decision-making for the conservation, management and sustainable use of the world's remaining mangrove ecosystems.

Despite efforts by several organizations, conventions and governments, the true value of mangroves and other wetlands is still underestimated. Much remains to be done to reduce the rate of loss, which is significantly higher than for other forest types. If deforestation of mangroves were to continue, it could lead to severe losses of biodiversity and livelihoods, in addition to salt intrusion in coastal zones and the siltation of coral reefs, ports and shipping lanes, with consequent losses of income from tourism and the loss of knowledge of mangroves and their use as recreational sites for coming generations. In a time of scenario development for the forestry and other sectors, Figure 17 clearly shows the two scenarios that local and international communities – together with governments and organizations – have to choose between for these valuable habitats.

The health of mangroves and of all the related marine and terrestrial ecosystems depends on their effective conservation and sustainable management.

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Annex 2

Regional working papers

FAO. 2007a. *Mangroves of Africa 1980–2005: country reports.* Forest Resources Assessment Working Paper No. 135, Rome. www.fao.org/forestry/site/mangrove/statistics.

Countries included: Angola, Benin, British Indian Ocean Territory, Cameroon, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Mauritania, Mauritius, Mayotte, Mozambique, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Togo, United Republic of Tanzania.

FAO. 2007b. *Mangroves of Asia 1980–2005: country reports*. Forest Resources Assessment Working Paper No. 136. Rome. www.fao.org/forestry/site/mangrove/statistics.

Countries included: Bahrain, Bangladesh, Brunei Darussalam, Cambodia, China, India, Indonesia, Iran (Islamic Republic of), Japan, Kuwait, Malaysia, Maldives, Myanmar, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, Sri Lanka, Thailand, Timor-Leste, United Arab Emirates, Viet Nam, Yemen.

FAO. 2007c. *Mangroves of North and Central America 1980–2005: country reports*. Forest Resources Assessment Working Paper No. 137. Rome. www.fao.org/forestry/site/mangrove/statistics.

Countries included: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos Islands, United States, United States Virgin Islands.

FAO. 2007d. *Mangroves of Oceania 1980–2005: country reports*. Forest Resources Assessment Working Paper No. 138. Rome. www.fao.org/forestry/site/mangrove/statistics.

Countries included: American Samoa, Australia, Christmas Island, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Micronesia (Federated States of), Nauru, New Caledonia, New Zealand, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna Islands.

FAO. 2007e. *Mangroves of South America1980–2005: country reports*. Forest Resources Assessment Working Paper No. 139. Rome. www.fao.org/forestry/site/mangrove/statistics.

Countries included: Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela (Bolivarian Republic of).

Annex 3
True mangrove species

See page 8 for the definition of true mangrove species adopted in this report.

Acanthus ebracteatus
Acanthus ilicifolius
Acanthus xiamenensis
Acrostichum aureum
Acrostichum speciosum
Aegialitis annulata
Aegialitis rotundifolia
Aegiceras corniculatum
Aegiceras floridum
Avicennia alba
Avicennia bicolor
Avicennia eucalyptifolia
Avicennia germinans
Avicennia integra
Avicennia lanata
Avicennia marina
Avicennia officinalis
Avicennia rumphiana
Avicennia schaueriana
Bruguiera cylindrica
Bruguiera exaristata
Bruguiera gymnorrhiza
Bruguiera hainesii
Bruguiera parviflora
Bruguiera sexangula
Camptostemon philippinensis
Camptostemon schultzii
Ceriops australis
Ceriops decandra
Ceriops somalensis
Ceriops tagal
Conocarpus erectus
Cynometra iripa
Cynometra ramiflora
Excoecaria agallocha
Excoecaria indica
Heritiera fomes
Heritiera globosa
Heritiera kanikensis
Heritiera littoralis
Kandelia candel
Laguncularia racemosa
Lumnitzera littorea
Lumnitzera racemosa
Lumnitzera x *rosea*
Nypa fruticans
Osbornia octodonta
Pelliciera rhizophorae
Pemphis acidula
Rhizophora x *annamalayana*
Rhizophora apiculata
Rhizophora harrisonii
Rhizophora x *lamarckii*
Rhizophora mangle
Rhizophora mucronata
Rhizophora racemosa
Rhizophora samoensis
Rhizophora x *selala*
Rhizophora stylosa
Scyphiphora hydrophyllacea
Sonneratia alba
Sonneratia apetala
Sonneratia caseolaris
Sonneratia griffithii
Sonneratia x *gulngai*
Sonneratia hainanensis
Sonneratia ovata
Sonneratia x *urama*
Xylocarpus granatum
Xylocarpus mekongensis
Xylocarpus rumphii

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FAO FORESTRY PAPER

The world's mangroves 1980–2005

Mangroves, commonly found along sheltered coastlines in the tropics and subtropics, fulfil important socio-economic and environmental functions: providing wood and non-wood forest products, protecting shores against wind, waves and water currents; conserving biological diversity; protecting coral reefs, sea-grass beds and shipping lanes against siltation; and providing habitat, spawning grounds and nutrients for a variety of fish and shellfish, including many commercial species. High population pressure in coastal areas has, however, led to the conversion of many mangrove areas to other uses. *The world's mangroves 1980–2005*, prepared in the framework of the Global Forest Resources Assessment 2005, provides comprehensive information on the current and past extent of mangroves in all countries and territories in which they exist. This information, as well as the gaps in information that come to light in the report, will assist mangrove managers and policy- and decision-makers worldwide in ensuring the conservation, management and sustainable use of the world's remaining mangrove ecosystems.